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THE SPROUL OBSERVATORY OF SWARTHMORE COLLEGE.

JOHN A. MILLER.

In April 1907, William Cameron Sproul communicated to the Board of Managers of Swarthmore College his desire to provide the funds with which to purchase an equipment for an astronomical observatory for the College. It was his desire that the chief instrument of this equipment should be a refracting telescope of "not less than twenty-four inches aperture," and that it be provided with such accessories as would enable the staff, which is limited in numbers, to pursue, under excellent instrumental conditions, at least one line of astronomical research. In June 1907, the College entered into a contract with the John A. Brashear Co., Ltd., to furnish the entire equipment provided for by Mr. Sproul including a telescope of twenty-four inches aperture with the usual accessories, a photographic doublet of nine inches aperture, and a measuring engine.

The photographic telescope was completed and installed in 1908; the twenty-four inch was completed and mounted in its observatory in December 1911, the long delay being due to a somewhat tedious wait of four years for discs out of which the lens could be constructed. The order for these discs was placed by the Brashear Company early in 1907, with Parra-Mantois & Cle, who, in August 1909, delivered a crown disc and would have, but for an unfortunate accident, delivered a flint disc the same year. Subsequently Schott and Gennossen of Jena also undertook the manufacture of a set of twenty-four inch discs. Both firms produced several flint discs which were either broken in annealing or were imperfect because of striae. Finally in February 1911, Schott and Genossen delivered a flint disc; accordingly, the objective is made of a crown disc made by the Para-Mantois & Cle, and a flint disc made by Schott and Genossen. Of the optical quality of these discs Mr. McDowell says that every optical test shows both these discs to be as nearly perfect as any he has ever examined; the crown lens can be rotated in any position relative to the flint on any axis, without affecting in any way the character of the image.

It is a pleasure to acknowledge the kindly consideration, the unceasing care, and the thoughtfulness of everyone connected with the Brashear Company, and to acknowledge the great value of the suggestions of Director Schlesinger, of Allegheny Observatory, during the construction of the instruments, and to say that in every way the entire equipment is excellent, even when measured by the high standard of excellence which characterizes the work of the Brashear Company.

The Student Observatory.

Swarthmore College is a small college founded by the Religious Society of Friends. The traditions of the college are, and always have been, that it is and shall remain a small college, and that its teaching energies shall be directed almost exclusively along undergraduate lines. It is the ambition of the present administration, however, to equip all departments of the college, so that first of all the teaching of the undergraduate shall be just as effective as it can be anywhere, and in addition to provide so far as possible library facilities and laboratory equipment so that the faculty of each department may engage in some line of research, with the hope of doing it effectively and producing creditable results. In almost every department, there are a few graduate students, but unless the student's interest and ability naturally lead him in the direction in which the professor is working, he is advised to pursue work in institutions that give their chief energies to graduate work. In accordance with this plan this equipment supplements, for purposes of research, a well equipped students' observatory which was placed on the College Campus about twenty years ago for instructional purposes. The funds for this observatory were secured through the efforts of Dr. Susan J. Cunningham, for thirty-five years Professor of Mathematics and Astronomy at the college, and since 1906 Professor Emeritus of Mathematics and Astronomy.

This observatory is only one of the expressions of the marked influence this great woman and great teacher has had, and in fact is having, upon the college, for she still contributes not only from her material resources, but gives her entire strength and influence to the upbuilding of the college.

The equipment of the student observatory includes a 6-inch equatorial refractor, the optical parts of which are by Alvan Clark, and the mounting of which, as complete as that of a large instrument, is by Warner and Swasey. It has as accessories, a position micrometer, and a spectroscope. There is a transit instrument, of three inches aperture, the optical parts and mounting of which are by the same makers. This instrument has a zenith telescope attachment. The observatory also contains a sidereal clock, a meantime clock, and a chronometer. The

entire equipment has been chosen most wisely and in such a way as to illustrate effectively many of the fundamental phases of astronomical research.

In 1910 Stephen Loines, a friend of the College, expressed a desire to add to this student equipment a 6-inch telescope, recently put out by the Alvan Clark and Sons' Corporation, and called by them a "Polar Equatorial"—a quasi Coudé. The tube of the telescope is mounted parallel to the earth's axis with the eye-end pointing towards the North Pole. At the lower end of the telescope a mirror, rigidly connected to the tube, reflects the object into the objective. The mirror is subject to two motions; one a rotation of the tube about its axis, thus setting off the hour angle, and the second a rotation of the mirror about an axis, at right angles to this one, thus setting off the declination. The telescope is provided with circles, reading hour angle and declination. The advantage of this mounting is that the observer while making his observations sits in a warm room in a comfortable position. The amateur finds it a most convenient instrument and it is used rather effectively and more or less extensively by students who merely want to "poke around the sky."

Descriptive astronomy in the college is elective, and, judging from the numbers enrolled in it, is a rather attractive course. There are enrolled in it at any one time from 15 to 20 per cent of the entire student body, which means that at least 60 per cent of the students who graduate from Swarthmore College, have done a year's work, meeting four times a week, in descriptive astronomy. One of these meetings is given to making observations with the telescope under best conditions, of at least one of each type of celestial phenomena. A considerable number of students use these telescopes for looking up objects, making micrometer measures, etc. The work is voluntary and no college credit is given for it. It can hardly be called serious work, but those who are interested and work faithfully derive a good deal of pleasure and considerable benefit from it.

A seismograph of the Milne type, presented to the college by Joseph Wharton, is mounted in a room adjoining the transit room. As is well known this instrument carries a horizontal pendulum, whose oscillations due to the vibrations of the earth's crust are recorded photographically. The instrument is very sensitive. It has recorded earthquakes from all parts of the world. There is a fairly continuous series of seismograms, extending through a long series of years, on file in the observatory. Some of these have been reduced but many have not.

The position of the transit instrument as determined by assistant Professor Barton is:

Latitude $= + 39^\circ\ 54'\ 23''.3$
Longitude $= 5^h\ 1^m\ 24^s.9$ W of Greenwich.

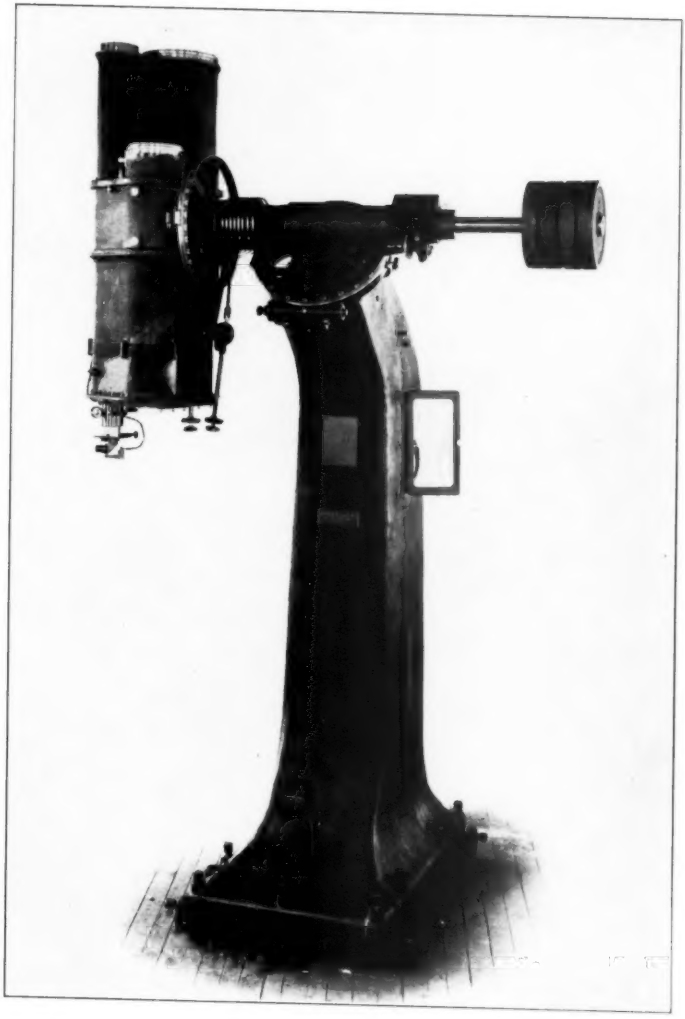
The Photographic Telescope.

The photographic telescope is installed in a building (the dome to the extreme left in Plate XV,) adjoining the student observatory, the dome covering it being 15 feet in diameter. The photographic lens is a doublet of nine inches aperture and 45 inches focal length. The optical quality of the lens is very satisfactory. A field of 6° or 7° diameter is fairly flat. When the center of the field is in the very best focus the image of a star 2½ degrees from the center is excellent. With the center slightly out of focus, one may secure passable star images out to the edge of an eight by ten plate. Numerous photographs of comets and star fields and nebulous regions have been made with this instrument. Since its mounting in 1908, practically all the comets that have appeared have been photographed and in the case of some of the brighter ones, namely, Comet Morehouse and Brooks' Comet, a fairly complete series of each has been obtained. Owing to meteorological conditions the series made of Halley's Comet is very incomplete. Something of the quality of the performance of the objective may be seen by reference to Popular Astronomy of December 1908, page 664, in which a picture of Comet Morehouse is reproduced. The mounting of this telescope is a practical duplicate of the Bruce telescope at the Yerkes Observatory. Parallel to the tube that carries the 9-inch doublet, is another tube to receive a 6-inch doublet, which has not yet been ordered, and a third tube also parallel to the other two carries a 5-inch visual telescope of about 47 inches focal length, used for guiding. The visual telescope is provided with a diagonal eye-piece, which may be shifted somewhat so as to displace the center of the photographic field from the center of the plate in the case of comets, and which may be rotated into any position that the observer desires. The three tubes carrying the lenses are bound very rigidly together and the mounting provides that one may, without interruption, photograph objects in any position through the meridian. The driving clock is very large and massive and performs remarkably well. The telescope is provided with both electric and hand slow motion, and with coarse and fine position circles. Plate XVI shows the photographic telescope.

The Sproul Observatory.

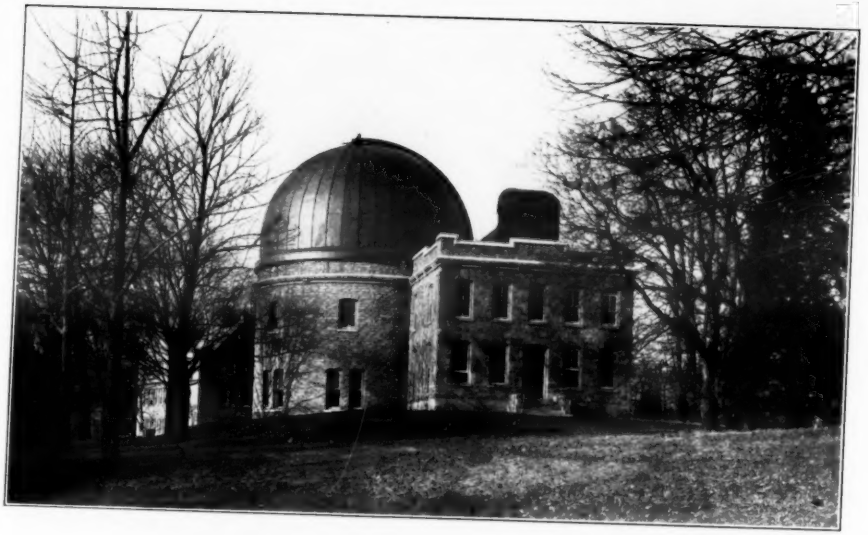
The 24-inch telescope and in fact the remainder of the equipment is installed in a new building erected for the purpose, situated on the college campus about an eighth of a mile from the student observatory. This building consists of a rectangular part two stories high in which are situated on the first floor, the office of the observatory, the library, a computing room, a shop room, and two class rooms. On the second

PLATE XVI



PHOTOGRAPHIC TELESCOPE OF SPROUL OBSERVATORY

PLATE XVII



SPROUL OBSERVATORY, SWARTHMORE COLLEGE

floor is a large lecture room, seating 76 people. This lecture room is equipped with a lantern and some other illustrative material; the photographic dark-room is also on this floor. A common hall leads into the lecture room, into the dome-room and into the dark-room. The 24-inch telescope is in a circular stone building adjoining the rectangular two story building just described, and is connected to it by a short hall. This circular building is surmounted by a dome covered with copper, 45 feet in diameter and was built by the Russell Wheel and Foundry Co., of Detroit, Michigan. The frame work is of structural steel, built in the shape of a cylinder five feet high, on which is surmounted a hemisphere, the center of motion of the telescope being in the center of the hemisphere. The lower end of the cylinder is fastened to a heavy circular iron base plate, planed true on the lower side, which rests on eighteen iron casters or wheels, sixteen inches in diameter, which are fastened to the wall of the building supporting the dome; that is, instead of wheels moving on a fixed track, the track or surface in contact with the wheels, moves over wheels with fixed centers. These wheels are provided with adjusting screws so as to bring them all to the same level and also on the circumference of a circle. The dome is rotated by an endless cable which passes over a drum driven by a four horse-power electric motor, which is controlled by a switch situated on the north side of the pier of the telescope. It requires four and one half minutes to turn the dome through one complete revolution. The mechanism works perfectly, except that the gearing makes a little more noise than is desirable.

The shutter is a large one, giving a clear opening of seven feet three inches. It is a double shutter, half of it moving to the right, while the other half simultaneously moves to the left. It is operated by a rack and pinion, which is driven by an endless rope.

The floor of the dome is stationary; this necessitates a rather large observing chair, which was built by our college carpenter. Warner and Swasey very kindly furnished the plans from which the observing chair of the Flower Observatory had been built, and our carpenter made such modifications as were necessary. The chair at first was very difficult to move, but since mounting it on large fiber casters secured from the Lansing Wheelbarrow Company, Lansing, Mich., it is possible to move it into any position with one hand and it is not at all unwieldy.

The Sproul Telescope.

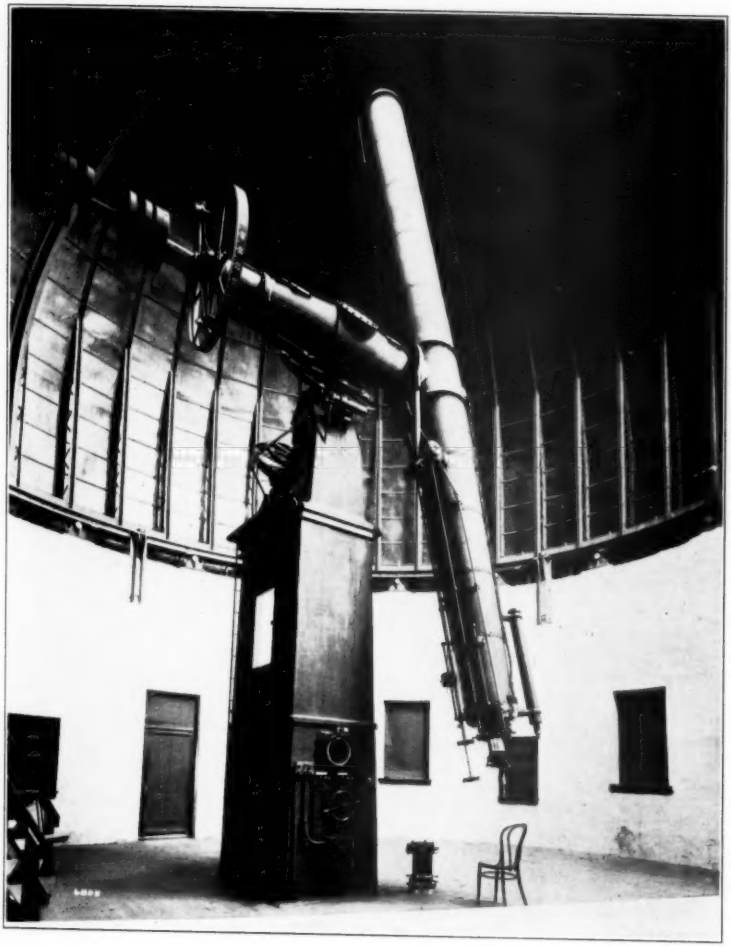
The mounting, as well as the optical parts of the Sproul Telescope, is by the Brashear Company. The mounting is an extremely heavy one weighing about fifty thousand pounds and in design is almost a duplicate of the mounting of the thirty-inch refractor of the Allegheny Observatory, the two mountings having been built at the same time.

The iron column rests on a concrete foundation which is set on a cushion of sand, the center of motion of the telescope being 28 feet above the concrete foundation. The polar axis rests on roller bearings in its journals, and a radial roller bearing takes the thrust of the axis. The worm wheel is 50 inches in diameter and seems to be of a high degree of mechanical perfection, The tube is made of heavy sheet steel and is very rigid. The center piece of the tube is of cast iron heavily ribbed; two rows of bolts running its entire length fasten the steel tubes to it. The distance from the center of the declination axis to the extreme outer part of the lens end of the tube is 19 1/3 feet; and from the center of the declination axis to the focal plane is 17 feet. From the center of motion of the telescope to the center of the tube is 54¾ inches, which allows a good clearance between the tube and the column when the telescope is pointed to the zenith.

The driving clock is an unusually heavy one, and depends for its control upon a conical pendulum which is actuated by a weight. When the weight driving the clock reaches its lowest point, it automatically completes an electric circuit, operating a motor which winds the weight up, and when the weight reaches its highest point it breaks the circuit. After the driving clock is started it runs continuously without the observer's attention. The clock is provided with two sets of gears, one of which drives the telescope at the sidereal rate and the other at the solar rate. The telescope is provided with the usual hand slow motions, operated in the usual way. In addition the driving clock is provided with an electric slow motion, which depends on a set of differential gears operated by a motor controlled by a switch at the eye end of the tube. The gears are thrown into train by a magnet which is operated by the same current that drives the motor; this renders necessary a rather complicated system of wiring, and for this reason requires considerable attention. The device has not been entirely satisfactory, probably because, since it is not indispensable, we have not given it the requisite attention. There is also an electric control for the driving clock. This is an old form of control; it depends upon the attraction of magnets for pieces of iron set in a brass circular disc whose plane is horizontal and whose center is the center of the vertical axis of the conical pendulum. The circuit through the magnets is closed once a second by a sidereal clock; hence, since the conical pendulum rotates once a second, the magnet will accelerate the pendulum if it is running slowly, and retard it if it is running fast, and not affect it if it is rotating just once a second. We have never used the control.

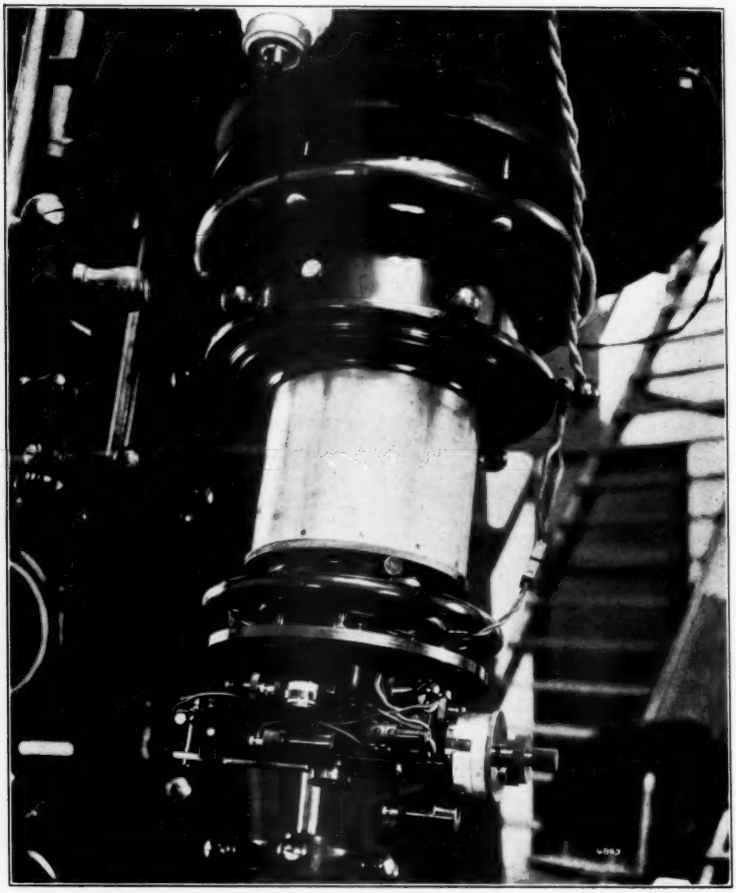
The telescope can be moved rapidly in right ascension and declination, either by hand or by a motor which runs in one direction only. This motion is communicated to the telescope by means of friction clutches

PLATE XVIII



THE SPROUL TELESCOPE

PLATE XIX



EYE-END SHOWING MICROMETER

operated by levers on the north side of the pier. There is a lever for right ascension and one for declination, the telescope being moved in a positive or negative direction according to the direction in which the lever is thrown. The operator thus may with one motor, running in one direction only, move the telescope in both right ascension and declination simultaneously, or separately, into any position. The motors, since their first adjustment, have worked perfectly.

Situated by the side of these levers is a right ascension dial, fourteen inches in diameter, the face of which is graduated on silver to minutes of time. This dial is driven by an eight day Thomas clock regulated to sidereal time, and rotating past a fixed index gives the time of the observation. A pointer geared to the polar axis indicates on the dial the right ascension of objects, so that neither addition nor subtraction is necessary. Having set the Thomas clock to the proper sidereal time and the pointer so that, when the telescope is pointed to a star, it indicates the proper right ascension, one may without any knowledge of the sidereal time, so long as the Thomas clock is kept running, set the telescope on any object whose position is known, by moving it until the pointer indicates the proper right ascension on the dial. If he desires also the approximate sidereal time he may read it from the dial. The only attention the mechanism requires is that the Thomas clock be wound once a week. The arrangement is an ingenious one and is a model of convenience.

The motor for operating the dome contains its own starting box, and can be reversed by simply reversing the switch. The other motors are so small that they do not need starting boxes, and the clutches are so arranged that the motor need never be reversed; so that one may operate any motor, or as many as he wishes at any time, about the entire mechanism by simply closing the proper switches,—a great convenience These switches, the right ascension dial, and the levers for operating the rapid motion of the telescope are on the north side of the pier and so near each other that all are within easy reach.

The current for operating these motors and for illuminating the circles is a 110 volt alternating circuit, which is furnished by the college. For illuminating the micrometer, the guide wires in the guide telescope of the photographic eye-piece, and a hand reading lamp, the 110 volt circuit is transformed into a 5-volt circuit. This is more convenient than storage batteries.

The Micrometer and Double Slide Plate Holder.

The telescope is provided with two pieces at the eye end, either of which may be fastened to the telescope by a bayonet joint. One of these pieces carries the tail-piece for focusing, to which is attached

either a position micrometer, polarizing helioscope, or the ordinary eye piece; the other carries a double slide photographic plate holder, and a focusing device.

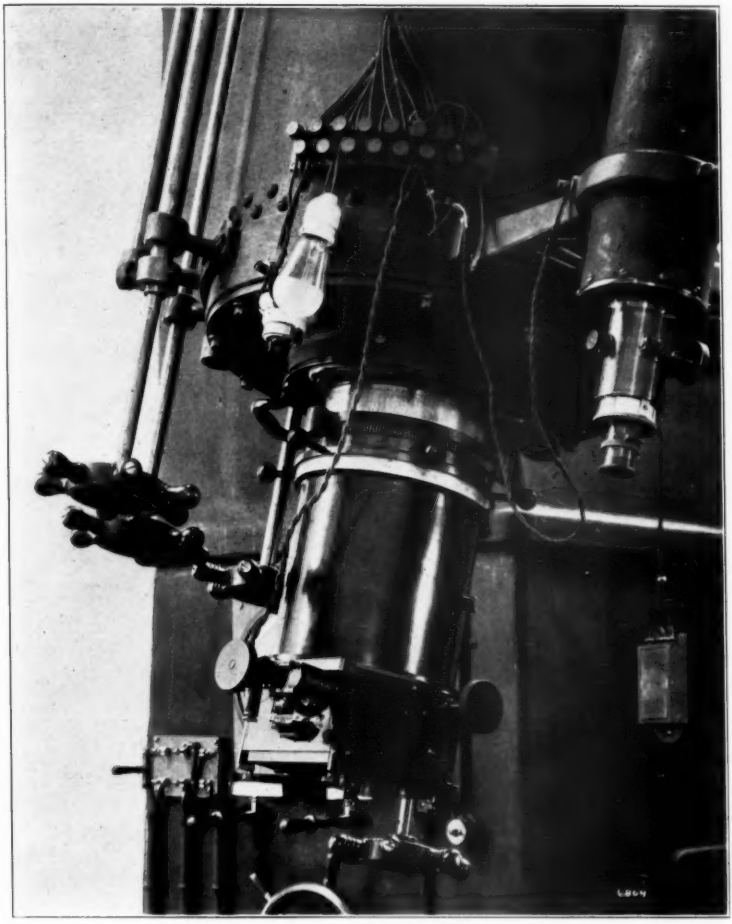
The position circle of the micrometer is nine inches in diameter, is graduated to degrees, and, by a vernier, reads to tenths of a degree. The screw, which is longer than usual, seems from preliminary tests to be very evenly cut. One turn of the micrometer screw equals 9″.27. The illumination of the micrometer is very complete and convenient. The position circle is illuminated at two points 180° from each other by miniature electric lamps, which are on the same circuit, and controlled by the same switch as a little miniature lamp that illuminates the micrometer head. The wires are also illuminated by miniature electric lamps. Mr. Klages, who designed the micrometer and in fact was responsible for the design of the entire mounting, spared no pains to make this micrometer complete and convenient—a remark indeed applicable to the entire mounting. The lamps illuminating the circles are provided with conveniently placed rheostats, entirely out of the way, and also with shields that prevent light not reflected from the circles from reaching the eye. Small low power lenses are over the position circle and move with the indicator. The intensity of the illumination of the wires is controlled by separate rheostats, not entirely conveniently placed, but out of the way. There is a device for changing the color of the illumination which is not very successful; in fact the method of illuminating the wires is capable of considerable improvement. The instrument is provided with all the ordinary conveniences, and in addition to these and those mentioned, an ingenious device for rendering the wires parallel to each other in case they were not set parallel originally.

The double slide plate holder is essentially the same as that devised by Ritchey for use at the Yerkes Observatory. This is described in Volume **12** p. 355 et seq. of the Astrophysical Journal.

The Objective.

The objective of the telescope is twenty-four inches in diameter and has a focal length of 432 inches; it is corrected for visual rays and is an excellent piece of optical workmanship. Soon after the telescope was mounted Professor Marriott and myself applied to the objective the method of extra focal images devised by Hartmann and described in the Publications of the Astrophysical Observatory of Potsdam. We covered the objective with a screen containing 44 circular holes 33mm in diameter. The centers of these holes were on nine different zones. Placing this screen we photographed Capella when it was near the meridian, photographing through a yellow ray filter, made by Wallace in accordance with the color curve of the objective. We used Cramer

PLATE XX



EYE-END SHOWING DOUBLE SLIDE PLATE HOLDER

Instantaneous Isochromatic plates. These plates when measured and reduced showed the presence of certain small astigmatic errors that Mr. McDowell asserted were not present in the objective when it was in the optical room. He surmised that it was due to the pressure of a spring used to prevent the objective from sliding in its cell. At Mr. McDowell's suggestion we repeated the test after reducing the pressure of the spring, using Arcturus instead of Capella, and using a screen containing 78 circular holes, distributed on ten zones. Notwithstanding the fact that Capella was photographed with the telescope east and Arcturus with the telescope west of the meridian, that one was north and the other south of the zenith, that the temperature was high when Capella was photographed and low when Arcturus was photographed, both tests showed qualitatively practically the same astigmatic errors, though they were smaller in the case of Arcturus than with Capella. These errors are not large,—in fact they are very small. With the values thus obtained we computed Hartmann's Characteristic T by which he measures the quality of an objective. Hartmann said when he devised this method of testing objectives that if T turned out to be less than 0.5, the objective is "preëminently excellent." The result which we obtained for the Sproul objective gives $T = 0.27$. If we grant this value of T to be correct this objective, according to the table given by Hartmann in Publications of the Astrophysical Observatory of Potsdam, is the third best in the world. We have decided however to repeat the extra focal test.

We are at present using the telescope for the determination of stellar parallax by means of photography; we photograph through the yellow ray filter mentioned above, on Instantaneous Isochromatic plates, and, when the seeing is good have suucceeded in getting small sharply defined images. For reducing the brightness of the parallax star we have used the occulting device designed by Schlesinger described in Astrophysical Journal Vol. 32 page 384. It has been found satisfactory.

Our observing program is made up pretty largely from the visual binaries whose orbits are fairly well determined. Some other objects of peculiar interest, for example Nova Geminorum, have been added.

The measuring engine upon which the plates are being measured was made by the Brashear Company. The plate is fastened into a heavy iron disc with an opening in it large enough to receive a 5x7 plate, the size that we are using. The disc is graduated, though not with extreme accuracy, and may be rotated about an axis perpendicular to its plane through any angle. The plate is fastened to a carriage, which may move up or down on guiding ways. The guiding way on the right supports one side of the carriage and also guides it. It consists of a triangular piece of iron accurately planed, fastened to the frame of the machine. This fits into a receptacle of the same shape inverted, fixed

to the movable carriage. The guiding way on the left consists of two planes, whose faces are in contact, and merely supports the left side of the carriage. We have not made what might be called definitive determination of the errors of these guiding ways, but preliminary tests show that they are not absolutely straight, though the errors in them are not large.

The microscope for measuring moves on a microscope way, at right angles to the guiding way, so that one may easily find any object on the plate. A scale, graduated to millimeters, 760 mm. long is set parallel to the plane of the plate. By a rather ingenious arrangement one may, by simply moving a small lever, change the microscope so that it reads either the scale or the plate, as he wishes. This scale seems to be very well made. We had it calibrated by the United States Bureau of Standards. The Bureau found that the distance between two consecutive divisions is just a millimeter for about one third of the marks, and that none are in error more than 1.5 microns, the probable error of the determination being in some instances as much as 0.6 microns.

The Observatory is open to visitors on the second and fourth Tuesday nights of each month, except during the summer vacation. Many people have availed themselves of this opportunity to see through the telescope, and when the night is clear and the weather is not too cold there are likely to be as many visitors as can be accommodated.

THE INTEGRATED SPECTRUM OF THE MILKY WAY.

E. A. FATH.

In Harvard Annals, 56, No. 1, is given a study of the distribution of the spectra of over 32,000 stars. Among other results are found: (1) That over 52 per cent of the stars investigated have A-type spectra; (2) the ratio of A-type stars to all other types increases as the brightness decreases; (3) in the Milky Way two-thirds of all the stars investigated are of the A-type. in view of these observations we might seem justified in drawing the following conclusions: (1) If we could get out into space far enough to view our entire stellar system, which we call the Milky Way, in somewhat the same manner as we can see the Andromeda nebula, and then analyze its light with a spectrograph the spectrum obtained would not be far different from that of an A-type star; (2) since we are probably situated somewhere near the center of the Milky Way system we could probably get some idea of the spectrum of the whole by taking samples of various parts. To do the latter it would be necessary to use

thousands of stars in each sample area and furthermore to get the light, not so much from the stars of the eighth magnitude, or brighter, but from the stars fainter than the eighth magnitude from which most of the light of the Milky Way is obtained.

It was manifestly impossible to treat such large numbers of stars separately with present appliances and so it was necessary to attempt the treatment of large numbers at the same time. The faint stars of the Milky Way are so numerous that the light coming from them may be considered as coming from a faintly luminous surface. In order to get the average spectrum of a luminous surface of appreciable angular area it is well known that a spectrograph whose collimator has an angular diameter equal to, or less than, the surface in question can be used without a telescope to gather the light. In fact the use of a telescope would cut down the amount of light instead of increasing it.

When the writer was studying at the Lick Observatory some years ago he had used a spectrograph of this nature to investigate the spectrum of the zodiacal light. Director Campbell very kindly loaned the same instrument so that it was possible to try it on the Milky Way. The exposures were made in the years 1911-12 at the Mt. Wilson Observatory.

The region selected for the first trial was the very bright portion of the Milky Way partially bounded by the stars γ, δ and λ *Sagittarii* which is the brightest region of the galaxy seen at this latitude.

The method of observation was the simplest possible. As stated above the spectrograph alone was used, as the angular diameter of the surface investigated was greater than the angular aperture of the collimator lens. The instrument was mounted in such a way as to permit motion in azimuth and altitude. It was then pointed at the region in question and moved every 10 or 15 minutes to follow the diurnal motion.

The first exposure was begun on the night of March 30, 1911, and continued whenever possible, until May 4. The total exposure on this plate * was $30^h\ 20^m$. As the spectrum obtained was not quite as strong as desired a second plate was taken in the interval from May 27 to June 29. The second exposure totaled $65^h\ 13^m$. It was of satisfactory intensity.

The general appearance of this spectrum is like that of the sun in that it shows the F, G, H and K lines and three broad absorption bands to the violet of K. On closer examination, certain differences can be noted but they do not appear to be of primary importance.

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* For a detailed description of the plates see Contributions of the Mt. Wilson Solar Observatory, No. 63, or Astrophysical Journal, **36**, 362, 1912.

It might be thought that the three stars γ, δ and λ *Sagittarii*, which are south and east of the star cloud under consideration and are of the K-type, might have an injurious effect, but that this is not the case is shown by measures of the brightness of the region with a photometer of the type used by Yntema and described in Groningen Publications, No. 22. A provisional reduction of these measures gives the brightness of a square degree of the Milky Way in this very bright region equal to approximately 0.4 the light of a standard first magnitude star. The total intensity of the light of the three stars is equal to half that of a star of the first magnitude. The angular aperture of the collimator lens may be taken as 3°. Accordingly the area of sky affecting the plate at any time was about seven square degrees. Then, assuming the most unfavorable condition possible, namely, concentrating the light from the three stars into one at the center of the region, this would amount to less than 1/5 of the total light falling on the plate at any time. As a matter of fact, these stars could send no light whatever to the plate unless the spectrograph was not moved at sufficiently short intervals of time. This occurred a few times, as it was necessary to carry on this exposure at the same time the writer was observing with the 60-inch reflector, and time could not always be taken to make the required changes. Had the exposure been made, either by having the spectrograph moved by a driving-clock or by continuous motion of the alt-azimuth mounting by the observer, the light of the three stars would never have reached the plate.

This result was of sufficient interest to continue the work, the same spectrograph being again loaned the following year by the Lick Observatory. The next plate was exposed a total of $67^h\ 52^m$ during May and June, 1912, on the bright region at $\alpha = 18^h\ 42^m$, $\delta = -8°$. This time the spectrograph was attached to the coelostat of the Snow telescope, a new set of gears providing the required speed of rotation. The plate is very much like the previous one except that it is not quite so dense.

A third exposure was made during July and August, 1912, on the region between β and η *Cygni*. This exposure amounted to $74^h\ 11^m$. The spectrograph was again attached to the coelostat of the Snow telescope. The intensity of this plate is about the same as that of the stronger plate of the *Sagittarius* region and the spectrum is similar in its appearance, although minor variations can be noted.

The four plates taken of three bright portions of the Milky Way are in agreement that *the integrated spectrum of the Milky Way is of approximately solar type.* This result is quite different from what had been expected but it receives an independent check from a series of plates taken to test the possible selective absorption, or loss, of light in

space. On the strength of the Harvard investigation that the greater portion of the Milky Way stars are of the A-type, and assuming that this result could be extended to the fainter stars, it appeared possible to test the hypothesis that the more distant, and therefore fainter, stars are redder than the nearer brighter ones.

The regions selected for trial were centered at

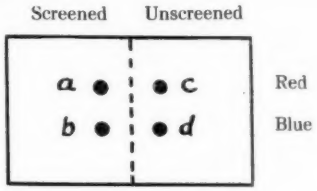
18^h	30^m	$+10°$	18^h	30^m	$+5°$
18	40	+10	18	40	+5
18	50	+10			

and photographed with the 60-inch reflector.

On each plate two exposures of a region were made, one through a red and the other through a blue ray filter, the plate being moved a little in declination to separate the images of the two exposures. In addition one half of the plate was kept covered by the slide of the plate holder except during 30^s at the close of each 6^m of the exposure. Thus on the covered or "screened" half of the plate only the brighter stars are found. Accordingly it is possible to compare faint stars from the uncovered portion of the plate with bright stars from the screened portion.

The theory of the method is as follows:

Let us consider two stars, one from each half of the plate, at the same distance from the optical axis so that there will be no differential aberration effect, and with the red images approximately equal. On the assumption that there is a greater absorption and scattering of blue than of red light in interstellar space, the blue image b will be larger than the blue image d.



Let us put

$$a - c = m \qquad (1)$$

$$b - d = n \qquad (2)$$

On the basis of our assumption the value $(n - m)$ will be positive, that is

$$(b - d) > (a - c)$$

Subtracting (1) from (2)

$$(b - d) - (a - c) = n - m = \text{redness} = r$$

or

$$r = (b - a) + (c - d)$$

If r is positive the more distant stars are redder than those nearer at hand. Should r prove to be negative then the more distant stars are bluer.

The plates taken were measured in the following manner. A circle of 38 mm radius was drawn with its center at the center of the plate. No stars outside the circle were used on account of the large aberration there. A star pair from the screened portion was then compared with any pair in the unscreened region that was approximately at the same distance from the center, the red images being as nearly as possible of the same size.

It will be unnecessary to go further into the details of this matter. The result of the comparison of 76 pairs of stars on the five plates showed that, in the mean, the fainter stars are distinctly redder than the brighter ones.* Had we been certain that the stars were all of approximately the same spectral type we should have strong evidence that the light from the fainter stars lost more of its blue than of its red components in traversing interstellar space as compared with the brighter stars. The spectrograms, however, offer another explanation, namely, the ratio of A-type stars to other types decreases as the stars become fainter, and, from a certain undetermined magnitude on, the stars of approximately solar type predominate, so that the fainter stars, which give us the most of the Milky Way light, are in reality redder than the brighter ones. These two investigations are therefore in agreement although the original purpose of the second is not served.

It is unfortunate that the regions selected for the second investigation were not identical with those of which spectrograms were obtained, but the former plates were taken first. It was not advisable to try a spectrographic exposure on these regions as they are too faint, the exposure required being probably in the neighborhood of 200 hours. The first spectrogram was obtained at about the same time as the other series of plates. The results of the latter were therefore not published in the form originally intended.

The Harvard investigation probably contains very few, if any, stars fainter than the eighth magnitude. Both the investigations discussed here deal almost exclusively with stars fainter than this. It would be a matter of interest to know at what magnitude the ratio of A-type stars to all other types reaches a maximum, as well as the magnitude

* This result is analogous to that found by Mr. E. S. King for bright stars and described in the January number of this magazine. However, he was able to use definite parallaxes, while in this case it was necessary to assume that, on the average, the fainter stars are more distant than the brighter ones. Mr. King also confined his investigation to "naked-eye" stars. His work is therefore not directly comparable with this.

at which the other types begin to predominate. From the material at hand, however, there seems to be no satisfactory method of obtaining these values.

In regard to the spectrographic exposures on the Milky Way it should be stated that every precaution was taken to prevent sunlight from any source reaching the plate. The exposures were not begun until the sky was thoroughly dark and were closed before dawn. Furthermore, no exposure was made while the moon was above the horizon.

If the result as given above should be found to be general it will have a bearing on cosmogonal theories but it must necessarily be accepted with some reserve until confirmed by additional work with a spectrograph of higher dispersion.

Smith Observatory,
Beloit College, Feb. 1913.

EXPERIMENTAL PROOFS OF THE EARTH'S ROTATION.

WILLIAM F. RIGGE.

[*Continued from page 216.*]

3. *The Compound Pendulum.* Strictly speaking the Foucault and Bravais pendulums are compound, but as they approximate to the definition of a simple pendulum more closely than those that remain to be mentioned, they deserve to be in a class by themselves. By a compound pendulum is here meant one that renders the diurnal rotation more evident, or keeps the time and amplitude of a pendulum constant, or increases the accuracy of the observation.

Franchot seems to have been the first to maintain the oscillations of a Foucault pendulum by means of an electromagnet. Garthe, who was the first to use a Cardan suspension, as mentioned before, also describes a clockwork contrivance due to Kabisch, which turned on two vertical steel pivots, and carried an index moving over a dial placed horizontally below the lower pivot. As the plane of vibration changed, it carried the clockwork with it, and indicated the angle on the dial. The instrument showed an hourly deviation of 10°.6 instead of 11°.7, a remarkable result in view of the enormous friction it entailed.

Porro suspended a short pendulum in a vacuum, attached a prism near the point of suspension, and observed the deviation and the axes of the elliptical trajectory with a telescope.

Foucault took up and perfected Franchot's electromagnetic contrivance to the extent that he made it absolutely independent of the pendulum itself, and exhibited it at the Universal Exposition in Paris in 1855. A single electromagnet was placed vertically under the lowest point of the pendulum. When the ball, which was of soft iron, was at the extremity of its swing, the circuit was closed and the ball attracted. As this attraction was mutual, the electromagnet was raised when the ball was nearest, and the circuit opened. The electromagnet fell back into place by the time the ball was at the other extremity of its swing, and thereby again closed the circuit. The vibrations could thus be kept up indefinitely and the deviation made very apparent.

Strange to say, this idea was expressed 70 years earlier by Poinsinet de Sivry, who proposed to make a mariner's compass without a magnet by maintaining the oscillations of a pendulum over a horizontal dial, by intermittent puffs of air. As the pendulum would keep its plane of vibration unaltered, it would show a change of azimuth exactly like a magnetic needle. Foucault, however, had the genius to use the whole earth as his ship.

Bernardi in Vicence in 1868 applied clockwork which kept the oscillations of the pendulum rigorously rectilinear. In 16.75 hours it showed a deviation of 190°.5, instead of the theoretical 179°.3.

Kamerlingh Onnes in 1879 made use of the suggestions of Porro and Gauss with notable improvements. His Cardan suspension carried a movable central part entirely devoid of knife edges. A beam of light was twice totally reflected from two prisms. He considers the Foucault and Bravais pendulums as two extreme forms of a spherical pendulum, and their elliptical perturbations as particular cases of the trajectory described by a mass that is not perfectly symmetrical in respect to its vertical axis. These trajectories are only modified forms of Lissajous curves, produced by the combination of two unequal pendular movements at right angles to one another. The experiments of Kamerlingh Onnes are the only ones in Father Hagen's estimation to merit the name of proofs of precision. His assistant, Father Stein, therefore devotes a special appendix of 72 pages to their mathematical discussion.

Two demonstration pendulums, which cast a beam of light on a screen, are worth mentioning. In Edelmann's form the weight is magnetized as a whole or in part and in its deviation continually directs a small piece of soft iron, which is supported below it and is furnished with a mirror. Berget's pendulum is a bronze rod one meter long carrying a copper weight of two kilograms. The deviations are read by a microscope or projected on a screen.

4. *The Hengler Pendulum.*—The horizontal pendulum was invented three times; by Hengler in 1832, Perrot in 1862, and Zöllner in 1869, all these inventions being independent of one another.

Hengler gives only a few details concerning his pendulum. He says that it extended in an east-and-west direction and that from its extremity a weight hung by a thread which could be lengthened to nearly a hundred feet. When the weight was raised, the arm of the pendulum is said to have swung towards the south. This is a qualitative result. Quantitatively he says that an elevation of the weight of only a few feet caused a noticeable deviation of the pendulum. These meager details deprive the experiment of all value. Hengler does not even give its theory.

Four years later Guyot performed a new experiment in the Pantheon in Paris in 1836. Knowing that a falling body deviates toward the east, he thought that a long plumb line should do the same. He therefore took a thread 57 meters long and attached two little balls to it, one near the top and the other near the bottom, and looked at their images in a basin of mercury placed underneath. He saw what he expected; the lower ball was 4-1/3 millimeters east of the upper one. Although Arago did not favor Guyot's work, he fell into the same theoretical error. He said that if two pendulums were set up east-and west of one another, one short and the other very long, that the line of the short one when produced would deviate to the east of the long one, not knowing that the centrifugal force on the earth's surface drives bodies towards the equator, that is, along the meridian. He does not even seem to have studied the theories of Gauss and Laplace, since he maintains that a falling body deviates to the east-southeast.

III. The Gyroscope.

The gyroscope, as used for our present purpose, consists essentially of a symmetrical torus, one point at least of whose axis of symmetry is fixed to earth, so that on account of its inertia and rapid rotation, it may show any displacement of its point of support and especially the diurnal revolution of the earth. A gyroscope is free, if it can turn through all three directions in space. It is constrained, if it can move in two directions only. A torus confined to turn in only one direction, cannot be called a gyroscope, because it cannot, as its name implies, show the motion of its point of support. Foucault was the first to use the word for a machine of his own invention.

The free and constrained gyroscopes behave very differently in the way in which they show the rotation of the earth. The former remains at rest independently of it, while the latter combines two rotational motions into one resultant. For this reason the constrained gyroscope is reversible, while the free one is not. Its theory, however, is very much more complicated.

A free gyroscope may also be called a universal one. A perfect machine of this kind is a mechanical impossibility; and it has therefore

been practically abandoned by experimenters. Among the constrained gyroscopes we class especially the horizontal and vertical types, according as their axes are confined to a horizontal or to a vertical plane. Foucault used all three.

1. *Foucault's Free Gyroscope.* Foucault saw that his pendulum showed only a relative displacement of its plane. He therefore felt himself forced to construct a machine that would keep its plane absolutely unaltered in space. Bohnenberger's apparatus, designed in 1817, seemed to be the best adapted for the purpose, since its torus was free to turn in all three directions, while its center of gravity remained in place. The friction, however, had to be reduced as much as possible. Foucault calls attention to three essential conditions verified in his own apparatus; the axis of the torus must turn with the least possible friction its circular support must be in indifferent equilibrium in any position, and the thread that supports the whole machine must be without torsion. His torus made about one revolution in a second and ran for eight or ten minutes. As the direction of rotation is a matter of indifference, this free gyroscope is not reversible. It is a curious fact that both the instruments designed by Foucault, the simple pendulum and the free gyroscope, are the only ones amongst all that have been used to prove the rotation of the earth, which are not reversible.

Person and Gilbert pointed out the inevitable defects of the free gyroscope, such as friction, want of perfect coincidence of its center of gravity with the intersection of its axes, the torsion of the thread, and especially the fact that when the disk is first set in motion, it is fixed to the earth and must therefore necessarily share its rotation. This impresses a new rotation upon the torus and appears as an imperceptible trembling of its axis.

2. *Foucault's Constrained Gyroscopes.* Foucault himself was quick to see the defects of the free gyroscope, and that this might be converted into a constrained one by fixing one or other of its supporting rings. Arnold in Boston in 1879 placed the plane of his torus perpendicular to the terrestrial equator and gave it a speed of twelve turns a minute alternately in opposite directions. It always inclined in the proper direction, as the theory demanded. But when he placed it parallel to the equator, it remained at rest, in whatever sense it was set rotating.

Gilbert reduced the vertical Foucault gyroscope to a much more simple and strong shape. He replaced its exterior ring by a contrivance in the shape of a horse-shoe mounted on a base, so that it would turn with considerable friction about a vertical axis. The interior ring was given a rhomboidal shape, and the knife edges were displaced 90°, so that the axis of the torus was vertical instead of horizontal. Gilbert

thus introduced an essential change into the Foucault instrument by replacing its indifferent equilibrium by a stable one. In experimenting with it, he placed small sliding weights upon the lower end of the rhomboidal frame. These weights served to give the axis of the torus a position of equilibrium at a definite inclination. This angle was a maximum in the meridian, and zero in the prime vertical. It increased in low latitudes and vanished at the poles, the very reverse of the Foucault pendulum. Gilbert called his instrument a baro-gyroscope. He also placed two tores upon it, with their axes parallel, and turning in the same sense. The deviation was increased, but its mechanical construction was less satisfactory.

Fleuriais has applied the baro-gyroscope to the sextant as an artificial horizon. The torus has a diameter of less than five cm and weighs less than 175 grams. It is set in rapid rotation by means of air currents, and then placed on the sextant back of the horizon glass, where it looks like a straight horizontal line. Baule has made a long series of observations with this instrument, and states that it is beyond all doubt affected by the rotational movement of the earth.

In order to obtain quantitative results, the speed of rotation of the torus must be known and kept constant. Krüger in 1851 first suggested an electric motor, but Garthe in Cologne in 1852 was the first to use one. He could not observe any effect due to the earth's rotation. He was evidently not in touch with the laws recently formulated by Foucault.

It is a pity that Gilbert did not apply an electric motor to his baro-gyroscope. The stabilizing gyroscope of Schlick, used in reducing the rolling of a ship, resembles the Gilbert instrument, although it was never intended to show the earth's rotation and does not do so.

3. *Föppl's Horizontal Gyroscope.* Foucault's horizontal gyroscope lends itself to simplification even more than his vertical, because both rings and the knife edges may be dispensed with. In his original instrument Föppl kept only the tore and its suspension. But he made the latter trifilar, instead of unifilar, and thereby introduced an exterior force that Foucault had tried to exclude completely. Its simplicity called for an electric motor, and this in turn suggested a double torus. Each torus was 50 cm in diameter and weighed 30 kg. Both were of cast iron, and fastened to the two ends of the horizontal axis of an electro magnet. This magnet was supported by three steel wires, while the wires supplying the current hung down loosely. The oscillations of the apparatus were dampened by four plates turning in oil, whose positions could be determined almost to the tenth of a degree. The number of revolutions in a minute, which ranged from 1500 to 2280, were deduced from the indications of a voltmeter, the trials lasting from

fifteen to thirty minutes. The movable parts of the apparatus were covered by sheet iron to exclude air currents. When the common axis of both tores was placed in the prime vertical, it showed a tendency to approach the meridian according to Foucault's law. As this tendency was resisted by the torsion of the trifilar suspension, the axis could turn over an angle of only 6°.576, or 0°.134 short of its theoretical value, thus giving an error of two per cent.

Garthe's electric gyroscope could also be used as a horizontal instrument. Unfortunately he did not know how to explain its action. His geostrophometer, which was never tried, was merely a vertical paddle wheel kept in motion by jets of water, the whole contrivance being mounted on pivots.

While the vertical gyroscope may serve to stabilize a ship, the horizontal one may replace its compass. The former has nothing to do with the earth's rotation, but the latter may be used as a mechanical demonstration of it. To insure its horizontality, the inventor Anschütz replaces Foucault's filar suspension by a basin of mercury. The rotation is maintained electrically. The instrument is of special service on war ships, where an ordinary steel compass would be subject to much disturbance. It has been tried on English, German and Italian vessels (1909). Poinsinet de Sivry's "compass without a magnet" has thus after more than a century taken practical shape.

IV. Constant Area Apparatus

The principle, according to which the instruments under this heading are grouped, is that known as the areal law, which requires the radius vector of a moving mass to sweep over equal areas in equal times.

1. *Poinsot's Bent Spring.* Next to that of Foucault's pendulum, Poinsot's idea of the bent spring in 1851 is the most interesting on account of its simplicity, at the same time that it is the least understood and most forgotten of all the ideas proposed. He suggested taking a straight and uniform piece of steel, supporting it at its middle by a thread, and then bending the extremities together in the form of a horseshoe and tying them with a string. When the apparatus is in perfect repose, the string is burned, and the spring straightens out again. It then behaves like a Foucault pendulum.

This simplicity itself seems to have occasioned much misunderstanding. Poinsot himself did not dream that his contrivance was reversible and could be made to turn faster than the earth. He imagined that the vertical plane of his instrument was more persistent than that of a pendulum, whereas it is rather less so. He also thought that the effect might be observed for an unlimited time, whereas the recoil of the spring can last only a few minutes. While Poinsot himself did not well

realize the value of his own idea, we shall see later that the three points mentioned offer some real advantages. Even the great Foucault seems not to have grasped the Poinsot idea perfectly. Certainly Baden Powell did not, nor did Tessan and Bertrand. Jullien, however, and Routh, and Furtwängler did.

2. *Baudrimont and Boillot's Suspended Balls.* Baudrimont in 1851 thought that if a ball was supported on an axis parallel to that of the earth, its inertia would make it independent of the earth's rotation, so that it would appear to rotate in the opposite direction. Boillot, 37 years later, had the same idea, and imagined that a ball hung by a thread must turn like a Foucault pendulum. He also proposed to eliminate all torsion by holding the axis with a magnet. Serpieri performed the experiment with a marble ball suspended by a soft iron wire seven meters long. The apparatus obeyed Foucault's law, but the ball showed no signs of rotation. In spite of this, Serpieri and Baden Powell persisted in their belief in the truth of Baudrimont's idea, and attributed the failure to torsion. Secchi and Chelini exposed its falsity. The reason is simple, because the ball has at the start the motion of the earth, like all other bodies in its neighborhood, and its own inertia keeps this up, so that the difference remains zero and the ball appears to remain at rest. Besides, if the idea were true, it would give us an easy way of getting perpetual motion.

3. *The Liquid Currents of Perrot, Combes and Tumlirz.* The fundamental idea of these experiments is that radial currents in a liquid ought to show a deviation on account of the earth's rotation. As these currents may be made to approach as well as leave the center, the experiment is reversible. In the former case the motion ought to be in the same sense as that of the earth, and in the reverse sense in the latter.

Perrot took a large circular basin full of water, which he allowed to stand for a whole day in order to insure its perfect quietude. Having spread some very light particles of wax along a radial line, he allowed the water to run out of a small orifice in the center. The particles deviated towards the right, as seen from the circumference of the basin, and their path became spiral toward the center. He gives no further particulars.

The inverse experiment of centrifugal currents presents much greater mechanical difficulties. Combes in 1859 suggested a method but never tried it. It was to receive a vertically upward jet of water into the middle of a cylinder, which was open at both ends, lying horizontally, and free to move around an axis coincident with the jet.

Without having any previous knowledge of Perrot's experiment, Tumlirz repeated it 50 years later in Vienna with much greater mechanical facilities. At the bottom of a vertical cylinder he placed a

vertical outlet pipe closed on the top but with holes on the side, so as to induce the outflowing water to take a horizontal direction. For this same purpose he made the water pass between two glass disks 5 cm apart and 140 cm in diameter, the upper one being slightly smaller. At the circumference of these disks the water was colored by small orifices containing methyl violet. The colored ribbons of water were very visible, although the velocity was only 1.11mm a minute. After 24 hours the level of the water had sunk only 17.5 cm. Great care was taken to admit the water in a perfectly vertical direction, and to insure an equal temperature throughout.

To prevent the formation of accidental currents, he allowed the water a long time to attain perfect rest, on one occasion as much as 40 hours. He performed the experiment six times and took photographs of the colored ribbons in the water, a whole day after it had begun to flow, by suspending his camera vertically over the tank. The deviation shown on the plates is notably less than that demanded by theory. While it is in three quadrants on all six plates in the proper direction, in the fourth, quadrant it is always in the wrong one. The cause of this anomaly seems to have escaped the experimenter. For this reason it is hardly possible to credit his results with a quantitative value, and even their qualitative determination may be questioned.

4. *Hagen's Isotomeograph.* Father Hagen concludes his work with the discussion of two instruments of his own invention. One is his modified form of Atwood's machine, which I have placed under the heading of falling bodies. This change of order seemed to me to be necessitated by my omitting the words "Old and New" from the title of this article.

His other instrument, which was however his first in the order of time, he calls an isotomeograph, because it shows the law of the constancy of areas by an equality of sectors. Its principle is the same as that of Poinsot's bent spring. In its first shape it consisted of a horizontal trussed beam, nearly 9 meters long, suspended by a wire in the thousand-year-old Leonine tower, which was nine meters in internal diameter with walls four meters thick and without any windows. The beam carried three pairs of basins at different heights, the upper and lower pairs being vertically under the point of suspension, while the middle pair were at the ends of the beam. Metal pipes allowed 160 kg of mercury to run from the upper pair of basins to the middle pair, and from these to the lower ones, the object being the transference of masses from the center of a horizontal and balanced beam to its extremities and the reverse.

In the second form of the apparatus, the mercury was replaced by two equal masses of lead, which were transported on small carriages, running on horizontal rails, from the center of the beam to its ends or vice versa,

by means of two cords and a weight hanging below. The mercury, as well as the lead weights, were set in motion by an electric current which burned out a fuse. All iron and steel were excluded from the construction in order to preclude magnetic disturbances. When the masses were transferred from the ends to the middle, the beam swung towards the left. It swung towards the right when they were moved from the center to the extremities. During the two years 1908-1910, 36 alternate trials were made, and the beam did not even once turn in the wrong direction.

The principle of the isotomeograph is neatly shown by a small rotational energy contrivance, which the writer of the present article lately purchased from a dealer in physical apparatus. It consists of two equal sliding weights at the extremities of a horizontal bar, which is supported at its center and can be turned around a vertical axis with any desirable speed. Cords are attached to the weights in such a way that they may be drawn inward simultaneously towards the axis. When this is done, the weights fly around much faster, but reduce their speed again when the cords are relaxed. The science of mechanics tells us that the moment of momentum of the system, that is to say, the product of the weights, their linear speed and their distance from the center must be constant. As the weights do not vary, it follows that the linear speed and the radius of the circle they describe are reciprocally proportional, each increasing as the other is diminished. Thus, if the radius is reduced one half, the linear speed is twice as great. As the circumference described is now one-half of what it was, the angular speed is four times as great, and the weights swing round four times as often as before. Since the area of the small circle is one-fourth that of the large one, the area swept over by the cord, technically the radius vector, is the same in a unit of time as it was at the start.

The same explanation applies to the isotomeograph. When the beam is apparently in absolute repose, it is in reality, like the tower itself and the ground, turning with the earth in anti-clockwise direction with a speed, which in Rome amounts to about ten degrees an hour, according to Foucault's law. When the weights are near the extremity of the beam, they turned with a certain rotational energy. When they are drawn inward, their angular speed is increased, and the beam must turn faster than it did at the start, faster therefore than the tower and the ground, and must apparently swing to the left or anti-clockwise. When the weights are near the middle of the beam at the start of a new experiment, their outward motion must turn the beam clockwise, since they now lose both linear and angular velocity at the expense of a larger radius.

The result was in perfect accord with the theory, the beam turning 0°.167 in a minute. It is scarcely necessary to remark that the experi-

ments were performed at night, that the room was tightly closed, and that the deflections were observed by means of a mirror upon the circular graduation on the wall.

Two defects, however, made themselves prominent, one being the want of sufficient precision in noting the position of the centre of gravity of the moving masses, and the other the uncertainty as to whether the rails at both sides of the beam were accurately in the same vertical plane. An improved apparatus is therefore under construction according to Tessan's idea, whose theory, however, is erroneous. The beam will consist of three parallel horizontal bars in the same plane, the outer ones being equal and bolted together, and the middle one having the mass of both of them. These bars will then be simultaneously drawn out or in. They will be made as light as possible and provided with heavy weights at their ends.

TOTAL ECLIPSE OF THE MOON, 1913 MARCH 21.

Dr. EDWARD GRAY.

On the evening of March 21 it was raining in Central California—at least in the Sonoma Valley,— and the prospects for seeing the total eclipse of the moon, due between three and four oclock in the morning (Pacific Standard Time), were very dubious. The rain came however in squalls, not continuously, and this fact afforded some measure of hope. About 2:30 a.m. (22nd) the clouds parted. Just after three o'clock one of the night attendants rang my telephone call and announced that the eclipse was visible and that the stars were out. The latter was true in patches or regions, not generally. I repaired hastily to my telescope house. On the walk thither the eclipse was so thorough that it cost me some trouble to locate the moon and many on night duty were unable to see the eclipse because of want of knowledge where to look for the moon. With the exception of the time it took for a small patch of cloud to pass over the moon I saw the eclipse well between 3:20 and 3:50. After a naked eye reconnoissance I observed first with my binocular field-glass. This showed a delicate crescent of subdued light upon the disappearing limb. Then observation followed through the finder and the telescope itself. All the instruments revealed the dull, coppery hue of the expanse of the moon's disk admirably. On viewing through the telescope I was struck with regret at once that I had not been called a full hour earlier; for there was the visible

record that the moon had just occulted two stars (simultaneously) in Virgo. After 3:45 clouds overspread Cygnus and nearly the whole sky, and it began to sprinkle. The emergent face of the moon was now showing the fact of receiving sunlight.

The weather through the day was squally, like the proverbial smiles and tears of April; and in the afternoon the sky furnished another spectacle of a different class. A little after four o'clock a squall was in progress against the eastern mountain-range (towards the N.E.) while the valley was sun-lighted. Between 4:05 and 4:08 occurred a meteorological phenomenon so unusual as to be unique so far as I can recall. Near the southern edge of the leaden clouds defining the squall was an arc of broad rainbow, perhaps 12° in length. This arc was *concave* to the sky, *convex* to the valley, and its colors arranged accordingly.

It could not be called a 'sun-dog', because it was in the quarter of the sky *opposite* to the sun, instead of concentric with it. If one could conceive the mirage of a rainbow at a lower level, it would answer the conditions perfectly. No leisure has been granted me since the occurrence to attempt to study out the philosophy of this remarkable sight. Perhaps some instructor in natural philosophy will volunteer an explanation. The meteorology of March 22, 1913 was altogether exceptional.

Eldridge, Cal.

THE TOTAL ECLIPSE OF THE MOON 1913, MARCH 21.

E. E. BARNARD.

This eclipse was observed here on a very clear sky but with the naked eye alone. The moon was poorly placed for observing, being low in the west. The total phase occurred in strong dawn or daylight. The moon would set near the middle of totality. No effort was made to photograph the total phase, for daylight and the low position among the trees would prohibit such work. But as a matter of curiosity alone, an attempt was made to get the contacts with the naked eye.

The penumbra was quite strong at $16^h\ 5^m$, and had been visible for some time and growing stronger.

First contact with shadow $16^h\ 14^m$.

For several minutes preceding this time the limb looked more or less flattened. This seemed to be due to the denser part of the penumbra. At the above time contact with the true shadow seemed to have actually occurred.

16^h 15^m. Shadow very marked at this time—quite a gap.

16^h 18^m. Four tenths of the radius covered. No trace of the eclipsed portion.

16^h 40^m. Could possibly feebly see the eclipsed portion, but uncertain—even when occulted by a tree.

16^h 43^m. Moon one half covered.

16^h 46^m. Could see the eclipsed part faintly without occultation, but not continuous all over the disc. It was too faint to recognize any color in it.

16^h 55^m. About 0.8 covered. The sky dark in the west as if no moon existed. Extremely clear with bright stars.

16^h 57^m. The eclipsed portion seen feebly.

17^h 3^m. Dawn everywhere—even near the moon. Could just see the eclipsed portion.

17^h 9^m. Very thin feeble crescent. Only the faintest traces of the eclipsed portion visible.

17^h 12^m. Not total yet, but very dim. Could see no trace of the eclipsed portion. Daylight strong everywhere.

17^h 13^m. Crescent still dimly visible on right hand side, but only as a feeble glow. Sky very white from dawn.

17^h 17^m. Still very feeble glow on the right hand side—all but gone.

17^h 19^m. Entirely disappeared. Actual totality doubtless occurred earlier.

17^h 20^m. No trace of the moon. Sky white from daylight.

The records are in Central Standard time or 6^h 0^m slow of G.M.T.

From the observations, I think it probable that this was a dark eclipse. The entire disappearance of the moon was doubtless due to the effect of the strong dawn or daylight. But in the partial phase the eclipsed portion seemed to be unusually dark.

It will be interesting to hear from observers farther west as to whether this was really an ordinary or a dark eclipse.

Yerkes Observatory, 1913, March 22.

THREE HUNDRED YEARS OF RESEARCH ON THE MOTIONS OF THE SATELLITES. 1610-1910.

KURT LAVES.

In our day when the celebration of anniversaries of scientific achievements is of such frequent occurrence, it seems an unfortunate oversight on the part of the astronomers, not to have commemorated the discovery or the invention of the telescope. Most likely, this is due to the fact that the exact date of the discovery and the name of the inventor are open to dispute. From an astronomical standpoint alone, there can be no doubt that to Galileo belongs the palm of the discovery, and that the seventh of January, 1610, gave to the world the first and most remarkable achievement of the new instrument. On this day Galileo saw, for the first time, the three inner satellites of Jupiter. To celebrate the tercentenary of this date would have been most fitting, since none of the other early telescopic discoveries has had a more far-reaching influence on contemporary thought and on the development of astronomy at large.

Galileo's discovery came to him as the crowning success of a series of great achievements in the realm of physics, which had given him the undisputed leadership among his contemporary colleagues. To him the overthrow of the time-worn Aristotelian principles and the introduction of the system of Copernicus was a matter of sacred conviction, and the ensuing clash between the new science and the old doctrines was inevitable. The fight was not confined merely to Pisa, where Galileo taught, but soon spread over Italy and beyond the Alps mountains. Kepler, the great contemporary and friend of Galileo, had just contributed to the world the discovery of his two fundamental laws of planetary motion, which he had obtained from the discussion of the observations of Mars. Great as this advance was for the maintenance and further development of the Copernican theory, it lacked the element of simple demonstrability to the minds of the untutored. Considered in this light, the discovery of a miniature solar world like that of Jupiter, in which four satellites moved about the primary body in circles, just as was postulated by the Copernican theory for the solar system itself, was an achievement of tremendous importance, a challenge to the Aristotelian school of most telling effect. Kepler's two laws obtained additional weight by the fact that these four satellites of Jupiter likewise fulfilled them, as was first shown by Kepler from the observations. When, seven or eight

years later, Kepler surprised the scientific world by the discovery of his third, the harmonic law, the study of Jupiter's satellites was sufficiently advanced to give proof that this law too is holding in the Jovian system.

From a scientific standpoint the first two decades of the seventeenth century represented the very "renaissance" under the leadership of the two extraordinary men, Galileo and Kepler. But soon the monstrous war of thirty years set an end to this blessed period and almost arrested science in its glorious advance.

We have so far considered the influence which Galileo's discovery had on the progress of the Copernican theory, but this discovery marks also an epoch in the art of astronomical observations. The very numerous eclipses of the satellites can be observed from the earth at all times, owing to the small inclinations of their orbits to the ecliptic. The precision with which such an eclipse could be observed even in those early days of astronomy was more than a hundred times greater than the precision which as skilled an observer as Tycho Brahe could attain with his mural circle. Long before the micrometer was invented a mass of observations was being secured which, even at the hands of an untrained observer, had micrometric accuracy. If Jupiter's equator had an inclination to the ecliptic like the equator of Saturn, eclipse observations would have been very scarce and only possible at intervals of six years, at the times when the plane of the equator and therefore the planes of the satellites would pass through the earth. The discovery of the satellites of Saturn, instead of those of Jupiter, at the critical period of 1610 would under no circumstances have had such a far-reaching influence on the progress of astronomy. Indeed from what has been said before, it is evident that the two great advances which followed the discovery of Jupiter's satellites could not have been made, or at least would have taken much longer to achieve. These two advances are: first, the method of determining the longitudes of stations on the earth by the eclipses of the first satellite, and second, and more important than the first, Roemer's great theorem of the propagation of light. We can here only allude to both. The former gave to geography the first precise method for cartographic purposes, the latter laid the foundation for a precise method by which the dimensions of the solar and the stellar systems could be determined.

Gradually the research on the satellites became a separate branch of astronomical science. The precision with which observations of eclipses of Jupiter's satellites could be obtained made it possible to detect long period inequalities long before their true nature was understood and before the planetary theory was ready for it. They appeared in the form of the inequality of 437 days, which is the characteristic inequality of the eclipses of the three inner satellites. It is not unlikely that Laplace

may have obtained from it the thought which lead to his discovery of the famous long period inequality in Jupiter's motion. From the ring system of Saturn he borrowed the leading idea for his famous Nebular Hypothesis, the bold coping of the *Mécanique céleste*. The gradual discovery of the numerous planetoids during the first half of the nineteenth century for a time diverted attention from the study of the motions of the satellites. An interlinkage of the two took place when the mass of Jupiter came out differently from the measurements of elongations of the satellites and the perturbative action of the planet on some of the asteroids in the neighborhood of Jupiter. This in turn created a new interest in the problem of the motions of the satellites, since it was now understood that the masses of the planets and also the positions of their equators could best be ascertained from the measurements of their satellites.

The retrograde motion of some of the new satellites and the rapidity of revolution of the innermost satellite of Mars called the attention of the astronomers again to the nebular hypothesis of Laplace and convinced them that this theory was far from explaining in a satisfactory manner the present conditions in the solar system. Just as long period inequalities first came to the notice of astronomers by way of the motions of the satellites, likewise the occurrence of cases of libration in Saturn's system of satellites opened up the study of similar motions among the planetoids. The recent discovery of asteroids of the Achilles group will very naturally link the two phenomena together. It is well known that new advances in the perfection of our means of observation have been followed by the discovery of new satellites.

After this preamble showing the importance which research on the satellites has had for astronomy, we will now turn our attention to the individual systems.

I. The Satellites of Jupiter.

When Galileo examined Jupiter with his telescope on the seventh of January, 1610, his attention was drawn to three small but very bright stars, nearly in line with the center of Jupiter and arranged so that two were to the east and one to the west of the planet. Quite accidentally he turned his telescope to Jupiter again on the following night and was startled by the fact, that the stars were now all on the west side of Jupiter. Strange to say, he did not yet hit upon the right explanation of the change but still believed that the bright objects were stars, and tried to account for the change in position by a direct motion of Jupiter with respect to the stars. The following night convinced him finally that this explanation was untenable and he discovered then the true character of the three objects. On the thirteenth

of January the fourth satellite was first seen by Galileo. Grant,* in his account of the discovery treats with disdain the claim of Simon Mayer, the discoverer of the Andromeda nebula, that he had discovered the same satellites independently of Galileo, and on almost the same day. It is, however, just to state that modern investigations have shown that Mayer's claim was well founded, he having seen the satellites on the eighth of January, 1610.

Galileo seems to have recognized from the beginning that the eclipses of the satellites would furnish a splendid method for the determination of longitudes, and his thought was taken up with great ardor by the astronomers of the seventeenth and eighteenth centuries, as is witnessed by the large number of contributions to learned societies of the period which report about determinations of longitudes by the new method. Galileo's early attempts to give tables for the prediction of eclipses were quite inaccurate. His countryman, J. D. Cassini, published, at Bologna in 1668, new tables which gained the confidence of his contemporaries. When Cassini was called to Paris to head the new Observatory, the interest in these eclipse-tables centered from that time in France, and the pupils and collaborators of Cassini devoted their main efforts to their improvement.

While Cassini was very successful as an observer, he seems to have lacked the ability to grasp and utilize new ideas suggested by others. When his great contemporary Ole Roemer, on the recommendation of Picard, was made Professor of Mathematics to the Dauphin, he devoted his superior acumen to the problem of Jupiter's satellites. He showed from a study of eclipses of the first satellite, that upon the assumption that the propagation of light is finite, the tabular values could be brought into close agreement with the observations. J.D. Cassini tried to combat the introduction of Roemer's equation of light by the apparently valid argument, that by it the tables for the other satellites would not be materially improved. In his new tables which appeared in 1693 he introduced in the case of the first satellite an empirical equation depending on the relative position of earth and Jupiter, which at bottom is nothing but Roemer's equation of light. The inaccuracy of the existing tables of the satellites was so great that only the eclipses of the first satellite were used for determining longitudes. The opposition of Cassini to Roemer's theorem did much to keep it for years in the background of astronomical interest and seriously impeded the research on Jupiter's satellites. Towards the end of the seventeenth century Fontenelli a writer of some renown remarks in one of his papers to the French Academy:†—"We must renounce, though perhaps with regret, the ingen-

* History of the Inductive Sciences.
† Grant's History.

ious and seductive hypothesis of the successive propagation of light..... How little prevents us from falling into great errors! If Jupiter had but one satellite.....we should have concluded with the utmost confidence that light traversed the annual orbit of the earth in 14 minutes." These remarks clearly indicate the critical condition in which Roemer's hypothesis found itself at this period.

Thirty years later Bradley discovered, by his careful observations of the declination of γ Draconis, the aberration of light and determined the constant as $16^{m}\ 26^{s}$. This proved to the world the accuracy of Roemer's hypothesis. A tendency to be dogmatic and despotic even in his scientific enunciations characterized Cassini, and his great renown as a successful astronomer made his pupils at the observatory believe implicitly in his dicta. It was thus considered an established fact that the orbits of Jupiter's satellites were true circles and that their planes coincided and had a constant inclination to the plane of Jupiter's orbit. The evidence on which these "fundamental laws" were founded was decidedly inadequate, and indications soon came to light to prove the elliptic character of the orbits and the variability in the positions of the planes of the orbits. As long as Cassini's doctrines were considered true laws of nature, there was no possible explanation for the apparent anomaly that the equation of light, while doing away with the irregularities in the motion of the first of the three satellites, would not do the same for the others. Indeed, now the thought gradually gained prominence that perturbations of some sort might be prevalent among the three outer satellites, which for some unexplained reason did not act on the first, and that these peculiar perturbations revealed themselves as the residuals between observation and calculation after the equation of light had been applied. Considering that the great genius of Newton was just then illuminating and modifying the concepts of planetary motion by the fundamental law of gravitation, one almost craves to see him likewise bring light into this puzzling problem of Jupiter's satellites. But strange to say, Newton never mastered this problem, although he had all the material ready for it, and actually investigated the motion of the fourth satellite.

We have seen in the introduction that the theory of satellites for the first time acquainted astronomers with the existence of long period inequalities. Considering the infinitesimal character of the masses of the satellites, it is indeed a daring thought to endow them with perturbative powers of the order of the residuals in the tables of the eclipses of the three outer satellites The school of Cassini was far from viewing the matter in this light, but did much through the labours of Maraldi I and II and Cassini II to prove that the laws of the founder of their school were not laws of nature.

The next advance came again from the north. The Swedish astronomer Wargentin published in 1746 tables of the satellites of Jupiter, which far exceeded in accuracy any that had yet appeared. The success which attended his labors is an encouraging illustration of the valuable results "which," as Grant expresses it, "may be achieved by a mind, even though gifted with no extraordinary powers, when all its energies are perseveringly directed to any specific object." Having collected all the observations which could be considered as worthy of any confidence, he instituted a careful comparison between them; and in this manner was led to form a number of empirical equations, which enabled him to represent the motions of the satellites with wonderful accuracy. He applied the equation of light to all the satellites, using Bradley's value of $16^m\ 26^s$, instead of 14^m as given by Roemer. Whilst the errors of the tables of the first satellite had formerly amounted to as much as 6 to 7 minutes, Wargentin reduced them to 1^m, mainly by applying an equation whose coefficient was $3^m\ 40^s$ with a period of $437^d\ 19^h\ 41^m$. This period is the famous eclipse period, to which we have previously alluded. He recognized it likewise in the motion of the second satellite, where its coefficient was determined to be as high as $16^m\ 30^s$ and, in 1759, in that of the third with a coefficient of but $2^m\ 30^s$. Wargentin discovered further two inequalities of much longer period in the motion of the third satellite, but we will not enter here into a discussion of these.

The period of 437 days, which first came to the notice of astronomers through Wargentin's investigations, had been found previously and independently by the great Bradley. In fact, the laurel of this discovery was withheld from him by an unfortunate coincidence of a nature similar to the one which befell Adams about 150 years later with reference to the discovery of Neptune. Bradley's discovery of aberration in 1729 gave him the means of using the correct value for the equation of light and on this account it would be quite consistent to credit him likewise with the discovery of the period of 437 days. Moreover he was the first to recognize the insufficiency of the empirical methods used by himself and Wargentin and he foretold in no uncertain terms that what was needed now for the research on satellites was the introduction of the analytic method founded on Newton's law of gravitation. In the meantime material was accumulating which showed conclusively that a number of inequalities existed in the motion of the fourth satellite which are very conspicuous in the changes which the inclination of the orbit undergoes. These could not be mastered by the clumsy empirical process employed till then.

Newton in considering only the perturbative action of the sun, had come to the conclusion that the node of the fourth satellite should *recede* on Jupiter's orbit about $5'\ 12''$ a year. The observations,

according to Maraldi II, showed an advance of about 4′ 13″ a year; this discrepancy between theory and observation was held by many to prove the incapability of the gravitational method to explain the motions of the satellites. In fact it was merely an oversight, although one fraught with sinister consequences, on the part of Newton, not to have taken account of the perturbative action of Jupiter's equatorial bulging and of the attraction of the third satellite. After Euler, in 1763, had examined carefully the effect of a spherical planet on the motion of a satellite and Clairaut had published his work on the motion of the moon, the time was ripe to attack the problem of Jupiter's satellites once more.

Bailly was the first to extend Clairaut's results to the problem of Jupiter's satellites, considering each satellite by itself. He discovered that the mutual attractions of the three inner satellites occasioned those inequalities in their motions which produce a regular return of their eclipses at the end of 437 days. These inequalities are analogous to the lunar variation, the only difference being that the disturbing body is in each case one of the satellites themselves and not the sun. On account of the masses of the satellites, these variations would become insignificant if there did not enter into the coefficient of each perturbative term a denominator of the form $n-2n'$, where n and n' are the mean daily motions of the first and second satellites. Now $n-2n'$ is very small indeed, and this fact gives to the inequality its great prominence. Since the periods of the three inner satellites are respectively $1^d\ 8^h$, $3^d\ 6^h$, $7^d\ 2^h$, Wargentin's inequality of a period of approximately 14 months has repeated itself more than 250 times since the discovery of the satellites. Since the orbit of I* nearly coincides with the plane of Jupiter's equator, the perturbing action from the oblateness of Jupiter exercises no measurable influence on the almost circular form of I, and II can be considered the only perturbing satellite, since III and IV are too far away, so that their attractions are likewise insignificant. Since the argument of the variation in longitude due to I has the argument $l-l'$ and the variation due to III has the argument $2l'-2l''$, the two blend and make the coefficient of the resultant inequality so large. This is due to the fact that there exists between the longitudes of I, II, III, the important relation $l-3l'+2l''=180°$; therefore we have $l-2l'=l'-2l''+180°$. From the coefficient of this resultant inequality Bailly was able to determine the sum of the masses of I and III while the coefficient of the inequality of I gave him a measure of the mass of II.

* It is customary to represent the four satellites in order by I, II, III, and IV and distinguish by no, one, two, and three accents the elliptic elements referring to them.

Bailly's results, remarkable as they are, were gained by faithfully following Clairaut's memoir on the moon. He assumed from the beginning the circular form of their orbits and did not enter into the characteristic nature of the problem. It was Lagrange who fathomed the real difficulties of the problem and laid the foundation for the successful theory of Jupiter's satellites in a memoir which the French Academy honored with its prize in 1766. Considering in a rigorous manner all the attractions acting on the four satellites, he writes out the system of twelve differential equations of the second order in rectangular coördinates. Neglecting first the eccentricities and inclinations, he obtains in the main the results already announced by Bailly for I II and III; the corresponding inequality of IV is found by him to be insignificant. Next he considers the inequalities dependent on the eccentricities and shows that each satellite under the conditions of the system must have four equations of center; one of these depends on the satellite's own eccentricity, the other three are the reflected effects of the eccentricities of the perturbing satellites. Coming next to the inequalities of the inclination and nodes, he discovered by the integration of his differential equations four inequalities of latitude corresponding to the four equations of center.

It is much to be regretted that Lagrange did not make his new theory the basis of eclipse tables, as he had originally planned to do. In this way all the glory went to Laplace, who gave his undivided attention to the new theory. In Lagrange's paper the inclination of Jupiter's equator to the plane of the orbit of Jupiter is neglected. Laplace soon found that this assumption, which simplified Lagrange's theory but slightly, obliterated very characteristic terms in the inequalities of the latitude. Omitting it, Laplace showed that the change of position of the orbital plane of a satellite could still be described in the happy Lagrangian way by the following geometric picture: on the unit sphere about Jupiter's center, we represent by S the pole of the great circle in which the satellite's orbit cuts this sphere, by E the pole of Jupiter's equator and by P the pole of the sun's orbit about the planet. Now the sun is considered one of the perturbers of the satellite's motion and the equatorial bulging of the planet is the other. If we neglect for a moment the influence of the satellites, then S will describe a spherical ellipse about a point, F, which is a fixed point on the arc E P. F may be called a spherical center of gravity between E and P; the stronger the equatorial bulging, the nearer F will be to E. The great circle of which F is the pole is called the Laplacian fixed plane for the satellite. We have for each of the satellites a particular "fixed Laplacian plane." The satellite's orbit regresses on its fixed plane, keeping a nearly constant inclination to it, or in other words the spherical ellipse, referred

to above, is nearly a circle. When the perturbative actions of the other satellites are taken into account, the pole of the resulting fundamental plane may be considered a center of gravity between the five disturbing poles in question. Thus Laplace expressed the latitude of each satellite by five terms: the first depended on the fixed plane with respect to the planet's orbit (original plane of reference), the second on the inclination of the satellite's plane to the fixed plane, the other three were determined by the positions of the nodes of the orbits of the disturbing satellites on the fixed plane.

The gradually increasing effect which the sun exercises on the motion in latitude becomes evident from the angular values of the distances of the poles of the four fixed planes from E; they are 7″, 63″, 302″, 24′ 33″. Now the motion of the plane of IV on Jupiter's orbit had been very irregular during the eighteenth century, and caused no end of difficulties to the explorers when they wanted to unravel its complex nature. It came from the fact that whilst the motion of the line of nodes of IV on the fixed plane is simple enough, the projection of this motion on Jupiter's orbital plane and the change of its inclination to the latter is quite complex.

The determination of the latitudes of the satellites by means of observations of eclipses has not the same degree of accuracy as the determination of longitudes. The reason for this is, that the former depends on the observations of the *duration* of eclipses, which are beset with a number of systematic errors. It will be seen later that the strict adherance to the observations of eclipses for the determination of the latitudes of the satellites has delayed the progress of the theory of the Galilean satellites by about one hundred years. The accuracy with which the longitudes of the satellites could be found from observations of eclipses gave Laplace a chance for a full display of his great analytical powers. It had long been known that simultaneous eclipses of the three satellites had never been observed. Simultaneous eclipses of II and III showed I in conjunction with Jupiter, and simultaneous solar eclipses caused by the passage of II and III in front of Jupiter found I in opposition. It was not difficult to see that the longitudes of the three satellites fulfill the following equation:

$$\text{(a)} \qquad l - 3l' + 2l'' = 180^\circ$$

The early investigators had soon found that $n - 2n'$ and $n' - 2n''$ is very accurately fulfilled, but it was left to Laplace to discover the important fact that to a very much higher degree of perfection the following equation is fulfilled:

$$\text{(b)} \qquad n - 3n' + 2n'' = 0^\circ$$

Pondering on the significance of both (a) and (b), he searched for a physical cause among the terms of the perturbative function. Laplace, in discussing the inequalities of the mean longitudes of the satellites due to their mutual attractions, discovered in each of them a term which, although it contains only the product of the masses of the perturbing satellites, is important since the argument is $\theta = l - 3l' + 2l''$. Combining the three differential equations in the longitudes in the manner in which θ is formed, a differential equation for θ itself is obtained, which is of the nature of the differential equation for the motion of a pendulum under gravity. The observations show that θ oscillates almost imperceptably about 180°; the period of the very slow oscillation is about six years.

The reader will understand that the perturbative terms which Laplace discovered are continuously exerting a restraint on the longitudes of the three satellites so that $l - 3l' + 2l''$ may not differ from 180° by more than an infinitesimal amount. If the relation between the longitudes has existed even only approximately at any time, the mutual attractions between the satellites will have caused this relation finally to become rigorously fulfilled, and to be maintained ever after, even against the influence of lesser outside perturbations, like the annual equation due to the action of the sun, or that caused by a resisting medium. In fact, these perturbations will be automatically distributed among the satellites according to the same subproportion which is existing between their mean motions, so that the equation between the longitudes will remain undisturbed. After the theory of the satellites had been fully developed, Laplace was able to determine the numerical values of the thirty-one constants which enter into his theory. They are the four masses of the satellites and the six elliptic elements of their orbits. Of these, eccentricity and major axis determine the size of an orbit, while inclination of the orbit to Jupiter's plane, longitude of the ascending node and longitude of the perijovium define the position of the satellite's plane and the orientation of the major axis in it. The sixth element is the longitude of the satellite at a certain epoch. Thus 28 constants are accounted for, the remaining three are the inclination and the ascending node of the equator of Jupiter on the plane of reference, and lastly the ellipticity of Jupiter's body.

The mass of a perturbing body is generally determined from the two disturbing effects it has on the motion of the perturbing body. It makes the line of apsides change its position in the course of time and brings about a change of position in the line of nodes, in which the perturbed body intersects the reference-plane. The three inner satellites of Jupiter have very nearly circular orbits and on that account the first form of perturbation is very difficult to observe. But we know from the

motion of the moon that the acceleration or retardation effected by the perturbing action of the sun in different quadrants makes itself felt from observations of transit over the meridian of the observer. Now the observations of the ellipse of the satellites are evidently similar to such transit observations and from them the inequality of 437 days had been found. Satellite I moves so nearly in the orbit of Jupiter's equator that the perturbing effect of Jupiter's inequality on its nodes is inappreciable, likewise is the inclination of the orbit of II too small to make itself felt sufficiently. But II creates in the motion of I the inequality of 437 days and this furnished Bailly a means of determining the mass of I. Satellite II is disturbed by I and III and besides by the perturbation due to the ellipticity of Jupiter (the influence of the sun and IV can be neglected.) The combined effect of I and III gives rise to an inequality in longitude of the same period of 437 days so that from the coefficient of this inequality a value for $m + m''$ is obtained. The change of the line of nodes of II is appreciable and is due mainly to the ellipticity of Jupiter but likewise to the perturbing effect of I and III. Thus a determination of the ellipticity is made possible from the observed change of the nodes of II. The most noteworthy inequality in the motion of III is an equation of center which IV forces on III. Lagrange's great contribution was to show that each satellite had, besides its original equation of center, three others introduced by the perturbing action of the companion satellites. Since the coefficient of that one which III suffers from IV is quite large the mass of IV is thus ascertained. We saw that IV is a satellite with a marked eccentricity and here the observations will reveal a change in the position of the line of apsides; this change is mainly due to the attraction of III and thus yields a value of the mass of III. The five data just mentioned lead to an approximate determination of the ellipticity of Jupiter and the masses of the four satellites.

Delambre, a pupil of Laplace, collected all the available observations of eclipses—some two thousand—and compared these observations with the calculated values derived from the theory of Laplace. In those days the famous method of least squares was not yet available for a systematic evaluation of the 31 unknowns which the problem required. Still Delambre very successfully coped with the problem and published tables for the future eclipses of the satellites, which have been the basis of all predictions of these phenomena by the various almanacs of the world. Since Delambre's eclipse-tables terminated about 1840, Damoiseau in 1836 published a continuation of them for another period of about 50 years. But he did not content himself with following in the footsteps of Delambre, but chose to reduce likewise the new observations made since the last reduction. Thus about 6000 observations were

compared with the theory. A number of the coefficients of his determination agreed with those given by Delambre, but there were quite a few in which Damoiseau's values differed from those of his predecessors. Unfortunately Damoiseau in his new tables fails to explain his reasons for changing some of the coefficients and retaining the value of Delambre's for others, nor is there any evidence that one and the same system of values satisfies his equations. Bessel was the first to look rather skeptically on the value of Damoiseau's contributions. Airy, quite independently of Bessel, came to the same negative estimate. But since no serious mistakes were recognized in the prediction of the eclipses, the matter was permitted to rest well nigh to the end of the nineteenth century. No one wanted to go through the redetermination of the 31 unknowns from the 6000 observations. And thousands of observations were still accumulating, so that it seemed a task far beyond the patience and endurance of a single investigator to reduce this gigantic mass of material. Hope was entertained that the Manuscript of Damoiseau, which was kept at the observatory of Paris, would finally dispel all fears as to the validity of his solution. Unfortunately this hope proved futile and even to this day the great desideratum remains to collect and reduce all the observations collected during the last three centuries and to build upon it a consistent theory. This evidently is a task which can be accomplished only by a large corps of trained computers such as we have at the Nautical Almanac office. Since by the recent international agreement of the directors of the Almanac offices much routine work which was previously done twice, or even more times over is now greatly curtailed, we feel hopeful that Jupiter's satellites may before long be given the attention which they deserve.

A notable advance in the theory of Jupiter's satellites was made when Souillart undertook to examine critically Laplace's theory. He found that quite a number of long period inequalities had been overlooked by the author of the Mécanique céleste; the coefficients of these terms are large enough to fall within the limit of accuracy set by Laplace's theory. In the theoretical presentation of the latitudes of the satellites it became likewise necessary to take account of the changes which Jupiter's orbit undergoes under the perturbing influence of the sister planets. These changes had been very carefully examined and computed by Professor Stockwell, and Souillart could readily apply his numerical results to the theory of the satellites. Unfortunately Souillart's numerical evaluation of the coefficients of his theory is not in keeping with his theoretical achievements; he adopted Damoiseau's values without examining critically the consistency of Damoiseau's mode of numerical calculations. What Adams so consistently did in his lectures on the satellites, viz., to obtain the masses from

Damoiseau's numbers and then to calculate the coefficients of the minor equalities, which were not derived from observations, should likewise have been done by Souillart. Souillart's theory is published in two volumes, the first appearing in 1879 in the publications of the Royal Astronomical Society, the other seven years later as a memoir of the Academy of Paris. This work greatly stimulated anew the interest of Jupiter's satellites. Although the tables of the eclipses of Jupiter's satellites had lost much of their general interest and importance in an age in which the determination of the terrestrial longitudes no longer depended on them, the theoretical interest in the peculiarities of their motions rather increased with the years.

To be Continued.

PLANET NOTES FOR JUNE, 1913.

The sun will be moving northward at the beginning and southward at the end of the month. It will reach its greatest declination north on June 21-22, which marks the time of the summer solstice. At this date the sun is said to enter the Sign of the Zodiac, Cancer, which marks the beginning of summer. It will move eastward from the constellation Taurus into Gemini.

The phases of the moon for the month are as follows:

New Moon	June	4 at	2 P.M.	C.S.T.
First Quarter		11 "	11 A.M.	"
Full Moon		18 "	12 M.	"
Last Quarter		26 "	12 M.	"

The moon will be nearest the earth on June 9 and farthest from the earth on June 24.

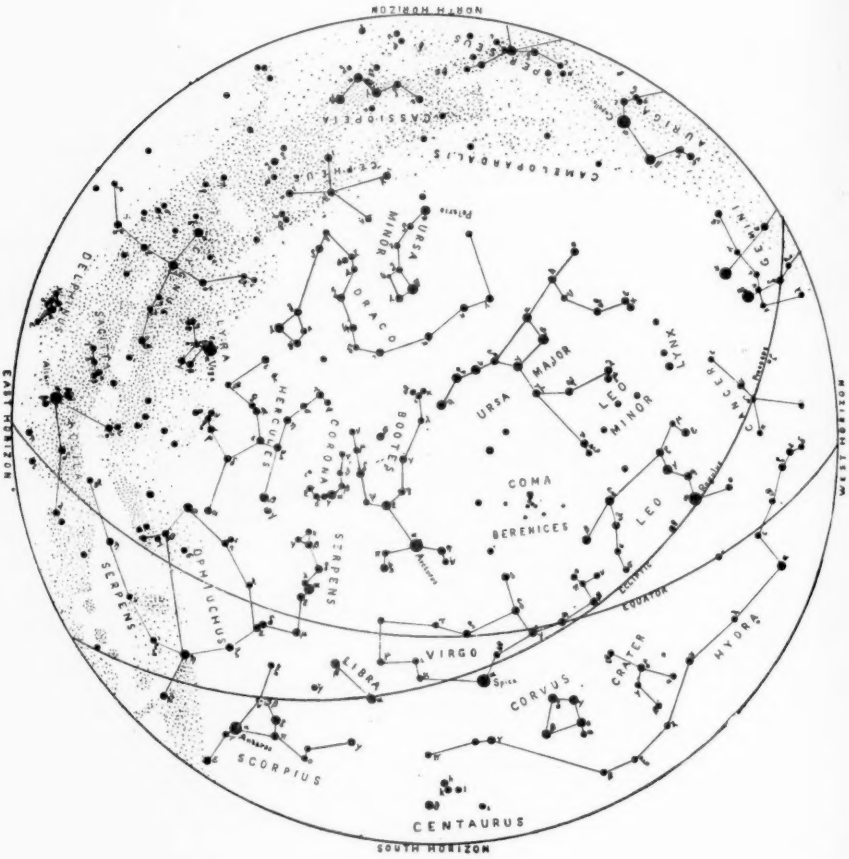
Mercury on June 1 will be on the opposite side of the sun from the earth and hence invisible. It will then move eastward much more rapidly than the sun, but will also move southward. By the end of the month it will be visible about ten degrees south of the sun, near the western horizon just after sunset.

Venus will be a few hours east and from eight to twelve degrees south of the sun. By the end of the month it will be approaching a period of greatest elongation west. It will be the brilliant morning star during this month. On June 23 it reaches a position of greatest distance from the sun in miles.

Mars will move slowly eastward and throughout the month will be rather near to Venus. It will therefore be visible only in the early morning, a few hours before sunrise.

Jupiter will continue to move westward throughout the the month. It will be 22 degrees south of the equator. By the end of the month it will be on the eastern horizon at sunset, and, except for its large declination south, will be in favorable position for observation.

Saturn will move slowly eastward. At the beginning of the month it will be too near the sun to be visible. By the end of the month it will rise about two hours before the sun. It will not be well situated for observation this month.



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1, 1913.

Uranus will be on the meridian a few hours before sunrise and will be in fairly good position for observation.

Neptune will be low in the west at sunset, and will be too near the sun for observation during the month.

Occultations Visible at Washington.

Date 1913	Star's Name	Magnitude	IMMERSION. Washington M.T. h	m	Angle f'm N. °	EMERSION. Washington M.T. h	m	Angle f'm N °	Duration h	m
June 12	*f* Virginis	6.0	8	6	150	9	17	289	1	11
13	550 B Virginis	6.0	12	26	112	13	28	298	1	2
18	C.D. —28° 14268	6.4	7	31	52	8	16	326	0	45
21	χ Capricorni	5.3	14	47	108	15	43	197	0	56
21	27 Capricorni	6.1	16	26	357	17	8	297	0	42
22	152 B Capricorni	6.5	11	8	5	11	40	313	0	32
24	317 B Aquarii	6.3	13	6	4	13	50	291	0	44

Phenomena of Jupiter's Satellites.

CENTRAL STANDARD TIME.

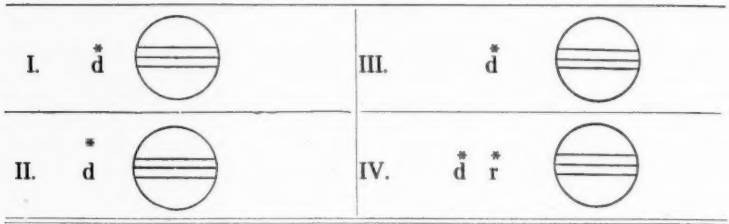
1913	h	m			1913	h	m		
June 1	10	11	II	Tr. In.	June 15	14	46	II	Tr. In.
1	11	20	IV	Tr. Eg.	17	11	41	II	Oc. Re.
1	11	27	II	Sh. Eg.	18	8	20	III	Oc. Re.
1	13	01	II	Tr. Eg.	19	14	47	I	Ec. Dis.
4	13	36	I	Sh. In.	20	11	52	I	Sh. In.
4	14	18	I	Tr. In.	20	12	13	I	Tr. In.
5	10	58	I	Ec. Dis.	20	14	10	I	Sh. Eg.
5	13	55	I	Oc. Re.	20	14	31	I	Tr. Eg.
6	10	22	I	Sh. Eg.	21	9	15	I	Ec. Dis.
6	11	02	I	Tr. Eg.	21	11	51	I	Oc. Re.
7	9	14	III	Sh. In.	22	8	39	I	Sh. Eg.
7	11	49	III	Tr. In.	22	8	57	I	Tr. Eg.
7	12	26	III	Sh. Eg.	24	10	38	II	Ec. Dis.
8	11	14	II	Sh. In.	24	13	55	II	Oc. Re.
8	12	29	II	Tr. In.	25	11	37	III	Oc. Re.
8	14	03	II	Sh. Eg.	26	8	33	II	Sh. Eg.
9	10	49	IV	Ec. Dis.	26	8	58	II	Tr. Eg.
9	13	16	IV	Ec. Re.	26	9	31	IV	Oc. Re.
10	9	25	II	Oc. Re.	27	13	46	I	Sh. In.
12	12	52	I	Ec. Dis.	27	13	57	I	Tr. In.
13	9	58	I	Sh. In.	28	11	09	I	Ec. Dis.
13	10	29	I	Tr. In.	28	13	35	I	Oc. Re.
13	12	16	II	Sh. Eg.	29	8	15	I	Sh. In.
13	12	47	I	Tr. Eg.	29	8	23	I	Tr. In.
14	10	06	I	Oc. Re.	29	10	33	I	Sh. Eg.
14	13	13	III	Sh. In.	29	10	41	I	Tr. Eg.
14	15	10	III	Tr. In.	30	8	01	I	Oc. Re.
15	13	50	II	Sh. In.					

Note:—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Satellites of Jupiter, June 1913.

WASHINGTON MEAN TIME.

Phases of the Eclipses of the Satellites for an Inverting Telescope.



Configurations at 12h 30m for an Inverting Telescope.

Day	West	East
1	○2· ·3 ·1 4·○	
2	·3 4· 2· ○ 1·	
3	·4 ·3·1 ○ ·2	
4	·4 ○ 1· ·3 ·2·	
5	4· 2· ○ ·1●	
6	·4 ·2 1·○ ·3·	
7	·4 ○ ·1 ·2 3·	
8	·4 3· 1· ○ 2·	
9	·3 ·2 ○ ·1 ·4●	
10	·3 ·1 ○ ·2 ·4	
11	○ ·1 3· ·2 ·4	
12	2· ·1 ○ ·3 ·4	
13	○1· ·2 ○ 3· ·4	
14	○ 1· ·3 ·2 ·4	
15	3· 1· ○ 2· 4·	
16	3· 2· ○ ·1 4·	
17	3· ·1 ○ 4· ·2●	
18	4· ○ ·3 1· 2·	
19	4· 2· ·1 ○ ·3	
20	4· ·2 ○·1 3·	
21	·4 ○ 3· ·2 ·1●	
22	·4 3· 1· ○ 2·	
23	·4 3· 2· ○ ·1	
24	·4 ·3 1· ○ ·2●	
25	4· ○·3 1· 2·	
26	·1₂. ○·4 ·3	
27	·2 ○ 1· ·4 3·	
28	○ 3··2 ·4 ·1●	
29	3· 1·○ ·1 ·4	
30	3· 2· ○ ·1 ·4	

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on April 1, 1913.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R.A. 1900. h m	Decl. 1900. ° ′	Magn.
T Androm.	0 17.2	+26 26	<12.0	V Can.Min.	7 1.5	+ 9 2	<13.0
T Cassiop.	17.8	+55 14	12.1	R Gemin.	1.3	+22 52	<11.0
Y Cephei	31.3	+79 48	9.1	R Can.Min.	3.2	+10 11	10.4*d*
U Cassiop.	40.8	+47 43	<12.0	S Can.Min.	27.3	+ 8 32	7.6
RW Androm.	41.9	+32 8	8.6*d*	U Can.Min.	35.9	+ 8 37	<13.0
W Cassiop.	49.0	+58 1	9.3 *i*	S Gemin.	37.0	+23 41	10.2 *i*
S Cassiop.	12.3	+72 5	<13.0	T Gemin.	43.3	+22 59	9.1
RU Androm.	32.8	+38 10	10.3	U Puppis	56.1	—12 34	<11.0
Y Androm.	33.7	+38 50	11.7 *i*	R Cancri	8 11.0	+17 36	9.1 *i*
X Cassiop.	49.8	+58 46	10.8	V Cancri	16.0	+17 36	8.2
R Arietis	2 10.4	+24 35	7.9	T Lyncis	16.4	+33 51	10.2
W Androm.	11.2	+43 50	12.0	U Cancri	30.0	+19 14	<13.0
Z Cephei	12.8	+81 13	12.2*d*	X Urs. Maj.	33.7	+50 30	<11.0
o Ceti	14.3	— 3 26	4.8 *i*	S Hydrae	48.4	+ 3 27	9.0*d*
S Persei	15.7	+58 8	8.2	T Cancri	51.0	+20 14	8.4
RR Persei	21.7	+50 49	<13.0	X Hydrae	9 30.7	—14 15	<11.0
RR Cephei	29.4	+80 42	13.1	Y Draconis	31.1	+78 18	14.2
R Trianguli	31.0	+33 50	5.4	R Leo.Min.	39.6	+34 58	9.2*d*
W Persei	43.2	+56 34	9.9	R Leonis	42.2	+11 54	6.6
U Arietis	3 5.5	+14 25	9.1*d*	Y Hydrae	46.4	—22 33	6.7
X Ceti	14.3	— 1 26	<12.0	U Hydrae	10 32.6	—12 52	4.5
Y Persei	30.9	+43 50	10.4	R Urs.Maj.	37.6	+69 18	12.2
R Persei	23.7	+35 20	<12.0	V Hydrae	46.8	—20 43	6.4
W Tauri	4 22.2	+15 49	9.4 *i*	S Leonis	11 5.7	+ 6 0	12.0
T Camelop.	30.4	+65 57	8.5	R Com. Beren.	59.1	+19 20	11.7
RX Tauri	32.8	+ 8 9	9.7	T Virginis	12 9.5	— 5 29	<12.0
X Camelop.	32.6	+74 56	10.7*d*	T Can. Ven.	25.2	+32 3	9.1
V Tauri	46.2	+17 22	9.5	T Urs.Maj.	31.8	+60 2	12.8
R Orionis	53.6	+ 7 59	9.4	R Virginis	33.4	+ 7 32	7.2
R Leporis	55.0	—14 57	7.5	RS Urs. Maj.	34.4	+59 2	10.7*d*
V Orionis	5 0.8	+ 3 58	11.2*d*	S Urs. Maj.	39.6	+61 38	10.3*d*
R Aurigae	9.2	+53 28	12.2	U Virginis	46.0	+ 6 6	10.5 *i*
S Aurigae	20.5	+34 4	9.0	RR Urs. Maj.	13 22.5	+62 55	<13.0
W Aurigae	20.1	+36 49	10.4	R Hydrae	24.2	—22 46	5.3
S Camelop.	30.2	+68 45	9.1*d*	S Virginis	27.8	— 6 41	<9.0
U Aurigae	35.6	+31 59	9.9 *i*	R Can. Ven.	44.6	+40 2	8.6
SU Tauri	43.2	+19 2	10.0	U Urs. Min.	14 15.1	+67 15	8.8
Z Tauri	46.7	+15 46	<12.0	S Bootis	19.5	+54 16	12.5
U Orionis	49.9	+20 10	10.6 *i*	RS Virginis	22.3	+ 5 8	<13.0
V Camelop.	49.4	+74 30	9.2	V Bootis	25.7	+39 18	10.1*d*
Z Aurigae	53.6	+53 18	9.9	R Camelop.	25.1	+84 17	9.0 *i*
V Monoc.	6 17.7	— 2 9	7.1	R Bootis	32.8	+27 10	<11.0
U Lyncis	31.8	+59 57	11.5*d*	S Libra	15 15.6	—20 2	9.4
S Lyncis	35.9	+58 0	<13.0	S Cor. Bor.	17.3	+31 44	7.9
X Gemin.	40.7	+30 23	11.0	RU Librae	27.7	—14 59	<12.0
Nova Gem. No.2	45.5	+32 17	8.7	S Urs. Min.	33.4	+78 58	11.6
W Monoc.	47.5	— 7 2	11.4	X Cor. Bor.	45.2	+36 35	8.2
Y Monoc.	51.3	+11 22	<12.0	V Cor. Bor.	46.0	+39 52	8.5
X Monoc.	52.4	— 8 56	8.2	W Cor. Bor.	16 11.8	+38 3	10.4 *i*
R Lyncis	53.0	+55 28	9.2	R Urs. Min.	31.3	+72 28	10.3
RS Gemin.	55.2	+30 40	<11.0	R Draconis	32.4	+66 58	11.6

Approximate Magnitudes of Variable Stars on April 1, 1913.

Continued.

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R.A. 1900 h m	Decl. 1900 ° ′	Magn.
S Herculis	47.4	+15 7	11.1	χ Cygni	46.7	+32 40	<11.0
R Ophiuchi	17 2.0	−15 58	10.5*d*	SV Cygni	20 6.5	+47 35	8.6
RT Herculis	6.8	+27 11	<11.0	RS Cygni	9.8	+38 28	8.0
T Draconis	54.8	+58 14	<11.0	R Delphini	10.1	+ 8 47	9.4
V Draconis	56.3	+54 53	<13.0	U Cygni	16.5	+47 35	7.9
T Herculis	18 5.3	+31 0	11.0	SZ Cygni	29.6	+46 16	9.5
W Draconis	5.4	+65 56	9.5	ST Cygni	29.9	+54 38	11.4
X Draconis	6.8	+66 8	13.8	T Aquarii	44.7	− 5 31	<10.0
R Scuti	42.2	− 5 49	5.2	X Cephei	21 3.6	+82 40	13.4
Z Lyrae	56.0	+34 49	10.6	T Cephei	8.2	+68 5	9.8
V Lyrae	19 5.2	+29 30	9.6	S Cephei	36.5	+78 10	9.5
S Lyrae	9.1	+25 50	<13.0	RV Cygni	39.1	+37 34	7.7
U Draconis	9.9	+67 7	12.2 *i*	V Cassiop.	23 7.4	+59 8	7.9
TZ Cygni	13.4	+50 0	11.1	Z Cassiop.	39.7	+56 2	<13.0
R Cygni	34.1	+49 58	7.9	RR Cassiop.	50.7	+53 8	10.5
TT Cygni	37.1	+32 23	7.6	R Cassiop.	53.3	+50 50	13.4
RT Cygni	40.8	+48 32	7.3	Y Cassiop.	58.2	+55 7	< 12.0
TU Cygni	43.3	+48 49	<12.0	SV Androm.	59.2	+39 33	11.4

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign < that the variable is fainter than the appended magnitude.

The above magnitudes have been compiled at the Harvard College Observatory from observations made by the following observers:—H. C. Bancroft, Jr., T. C. H. Bouton, A. B. Burbeck, A. P. C. Craig, E. L. Forsyth, C. E. Furness, N. V. Ginori, E. Gray, F. E. Hathorn, S. C. Hunter, M. W. Jacobs, Jr., J. B. Lacchini, F. C. Leonard, C. Y. McAteer, W. T. Olcott, P. G. O'Reilley, F. E. Seagrave, H. M. Swartz, D. Todd, H. W. Vrooman, I. E. Woods, A. S. Young.

Minima of Variable Stars of Short Period.

[Calculated by Myrtle L. Richmond, E. R. Peterson and S. N. Stearns at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain eastern Standard time subtract 5^h; Central Standard 6^h, etc.

Star	R. A. 1900 h m	Decl. 1900 ° ′	Magnitude	Approx. Period d h	Greenwich mean times of minima in **June** 1913 d h d h d h d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.9	6 23
RT Sculptor	0 31.5	−26 13	9.6—10.5	0 12.3	2 7; 9 23; 17 15; 25 8
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	4 18; 12 5; 19 15; 27 2
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	1 23; 9 10; 16 22; 24 9
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	2 23; 9 2; 21 7; 27 10
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	6 18; 13 15; 20 11; 27 8
RZ Cassiop.	39.9	+69 13	6.4— 7.8	1 04.7	1 11; 8 15; 22 23; 30 3
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	6 16; 14 15; 22 13; 30 12
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6	15 19
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	5 15; 11 9; 22 20; 28 13
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	2 12; 9 7; 22 22; 29 17
λ Tauri	55.1	+12 12	3.4— 4.5	3 22.9	6 14; 14 11; 22 9; 30 7
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	6 18; 15 1; 23 9
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	5 4; 11 2; 22 22; 28 20

Minima of Variable Stars of Short Period.—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean time of minima in **June** 1913
	h m	° ′		d h	d h d h d h d h
RW Persei	4 13.3	+42 04	8.8—11.0	13 04.8	6 17; 19 22
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	2 13; 8 20; 21 11; 27 18
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	3 13; 16 0; 28 10
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	6 12; 13 4; 19 20; 26 12
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	3 8; 14 6; 25 4; 30 15
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	6 1; 12 2; 24 3; 30 3
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	6 0; 12 11; 18 23; 25 12
SV Gemin.	5 54.6	+24 28	9.8—<11	4 00.2	1 16; 9 16; 17 16; 25 17
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	2 16; 8 10; 19 21; 25 14
U Columbae	6 11.2	−33 03	9.4—10.2	2 19.2	4 19; 10 10; 21 15; 27 5
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	3 12; 14 11; 25 9; 30 20
RW Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	3 5; 10 20; 18 10; 26 1
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	4 8; 16 13; 28 18;
RU Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	4 22; 12 2; 19 6; 26 10
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	3 8; 9 0; 20 9; 26 1
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	2 22; 12 5; 21 13; 30 20
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	3 15; 10 6; 23 11; 30 2
RR Puppis	43.5	−41 08	9.5—	6 10.3	2 15; 9 1; 21 22; 28 8
V Puppis	7 55.4	−48 58	4.1— 5.8	1 10.9	3 19; 11 2; 18 8; 25 15
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	1 1; 11 21; 22 17; 28 3
S Cancri	38.2	+19 24	8.2—10	9 11.6	3 9; 12 21; 22 8
S Antliae	27.9	−28 11	6.7— 7.8	0 07.8	3 0; 9 12; 12 11; 28 22
S Velorum	28.5	−44 46	7.8— 9.1	5 22.4	3 7; 9 5; 21 2; 27 1
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	7 4; 15 14; 24 0
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	7 6; 16 13; 25 20
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.0	4 14; 11 5; 17 19; 24 10
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	8 10; 17 5; 26 0
RW Urs. Maj.	35.4	+51 34	9.3—10.3	7 07.9	6 9; 13 17; 21 1; 28 9
Z Draconis	11 40.6	+72 48	9.5—12.5	1 08.6	4 21; 11 16; 18 10; 25 5
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	6 3; 13 13; 20 23; 28 10
δ Librae	14 55·6	− 8 07	5. — 6.7	2 07.9	7 20; 14 20; 21 20; 28 19
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	5 0; 11 22; 18 20; 25 17
TW Draconis	32.4	+64 14	7.0— 8.9	2 19.4	6 6; 14 16; 23 2
114.1908 Librae	15 43.4	−64 14	9.3—11.5	0 18.4	3 10; 11 2; 18 17; 26 9
SW Ophiuchi	16 11.1	− 6 44	9.2—10.0	2 10.7	5 20; 13 4; 20 13; 27 21
SX Ophiuchi	12.6	− 6 25	10.5—11.2	2 01.5	3 1; 11 7; 19 13; 27 19
R Arae	31.1	−56 48	6.7— 8.	4 10.2	9 8; 18 4; 27 0
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	9 9; 19 2; 30 3
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	5 5; 12 0; 18 19; 25 14
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	4 19; 13 4; 21 14; 29 23
u Herculis	13.6	+33 12	5.1— 5.6	2 01.2	5 17; 11 20; 24 4; 30 7
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	7 6; 14 11; 21 16; 28 21
RV Ophiuchi	29.8	+ 7 19	9. —<11	3 16.5	4 5; 11 14; 18 23; 26 8
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	7 21; 16 2; 24 6
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	7 17; 15 6; 22 19; 30 8
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	6 23; 14 22; 22 22; 30 22
WX Sagittae	53.6	−17 24	9.2—10.8	2 36.6	5 4; 11 14; 24 8; 30 18
WY Sagittae	17 54.9	−23 1	9.5—10.6	4 16.0	1 4; 10 12; 19 20; 29 5
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	5 0; 15 9; 25 17; 30 21
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	3 3; 10 9; 17 15; 24 21
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	2 2; 8 23; 22 19; 29 17
RZ Scuti	21.1	− 9 15	7.4— 8.3	15 3.2	7 22; 23 1
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	2 23; 13 23; 24 23; 30 12
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	1 1; 9 23; 18 20; 27 17
SX Sagittarii	39.7	−30 36	8.6— 9.4	2 01.8	2 11; 8 16; 21 3; 27 9
RR Draconis	18 40.8	+62 34	8.5—<12	2 19.9	3 21; 12 9; 20 21; 29 8
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	2 20; 9 11; 22 18; 29 9
β Lyrae	46.4	+33 15	3.4— 4.5	12 21.8	8 13; 21 11
U Scuti	18 48.9	−12 44	9.0— 9.8	0 22.9	1 9; 10 22; 20 11; 30 0
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.5	1 0; 8 14; 16 3; 23 17

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in **June** 1913							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
RV Lyrae	12.5	+32 15	11. —13	3 14.4	7 15;	14 20;	22 0;	29 4				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	6 20;	15 18;	24 17					
U Sagittae	14.4	+19 26	6.7— 9.0	3 09.1	3 19;	10 13;	24 2;	30 20				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	3 18;	11 2;	18 11;	25 20				
TT Lyrae	24.3	+41 30	9.0— <11	5 05.8	2 20;	13 8;	23 20;	29 2				
120.1907 Draconis	19 26.2	+68 44	9.3—10	1 15.1	2 17;	9 6;	22 7;	28 19				
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	5 8;	11 8;	23 8;	29 8				
WW Cygni	20 00.6	+41 18	9.5—12.5	3 07.6	1 19;	8 10;	21 17;	28 8				
SW Cygni	03.8	+46 01	9. —12	4 13.8	8 0;	17 4;	26 7					
VW Cygni	11.4	+34 12	9.5—11.5	8 10.3	4 4;	12 15;	21 1;	29 11				
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	2 20;	9 15;	23 5;	29 23				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	2 8;	9 6;	23 1;	29 23				
W Delphini	33.1	+17 56	9.5—11.5	4 19.4	4 10;	14 1;	23 16					
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	2 22;	12 3;	21 8;	30 13				
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	2 2;	9 14;	17 2;	24 14				
WZ Cygni	49.3	+38 27	9.8—10.8	0 14.0	3 1;	8 21;	20 13;	26 10				
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	4 16;	14 18;	24 21;	29 22				
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	2 21;	10 6;	17 16;	25 1				
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	1 10;	11 2;	20 19;	30 12				
UZ Cygni	55.2	+43 52	9. —11.5	31 07.3		19 12						
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	5 2;	15 6;	25 9;	30 11				
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	3 12;	13 21;	24 6;	29 10				
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.6	2 18;	13 15;	24 12;	29 23				
TT Androm.	23 08.7	+45 36	10.5—11.3	2 18.3	8 9;	16 16;	24 23					
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.4	6 19;	14 7;	21 20;	29 9				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	4 14;	12 20;	21 2;	29 7				

Maxima of Variable Stars of Short Period.

[Calculated by May E. Abbott, Hazel H. Barnard, Helen A. Orr, and Myrtle L. Richmond at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in June 1913.							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.4	36 13.7		4 3						
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	3 4;	11 8;	19 11;	27 14				
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	4 17;	12 10;	20 4;	27 22				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2		14 17;	29 12					
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 14;	13 12;	21 11;	29 9				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	7 6;	15 1;	22 20;	30 15				
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	7 2;	14 9;	21 16;	28 22				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0		2 0;	18 0					
SX Persei	4 10.2	+41 27	10.4—11.2	4 06.9	2 22;	11 12;	20 2;	28 16				
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	3 20;	14 23;	26 2					
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0		12 14;	24 5					
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	2 2;	19 18;	17 9;	25 1				
SY Aurigae	05.5	+42 42	8.4— 9.5	10 03.3	2 15;	12 18;	22 22					
Y Aurigae	21.6	+42 21	8.6— 9.6	3 20.6	1 6;	8 23;	16 16;	24 9				
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	2 20;	13 21;	24 23;	30 11				
RS Orionis	6 16.5	+14 43	7.8— 8.5	7 13.4	2 10;	9 23;	17 12;	25 2				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		6 7						
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	2 17;	9 22;	17 3;	24 7				
W Gemin.	29.2	+15 24	6.8— 7.6	7 22.0	4 17;	12 15;	20 13;	28 11				
ξ Gemin.	6 58.2	+20 43	3.7— 4.5	10 03.7	2 5;	12 8;	22 12					
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5		17 2						

Maxima of Variable Stars of Short Period.—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in June 1913.
	h m	° ′		d h	d h d h d h d h d h
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	3 2; 11 1; 18 23; 26 22
V Carinae	8 26.7	−59 47	7.2— 8.0	6 16.7	1 22; 8 14; 22 0; 28 16
T Velorum	8 34.4	−47 01	7.5— 8.5	4 15.3	2 19; 12 1; 21 8; 30 15
W Carinae	9 19.2	−55 32	7.5— 8.5	4 08.9	2 10; 11 4; 19 22; 28 15
W Ursae Maj.	9 36.7	+56 24	7.9— 8.6	0 04.0	7 0; 13 16; 20 9; 27 1
RR Leonis	10 02.1	+24 03	9.1—10.1	0 10.9	1 19; 8 14; 22 3; 28 22
SW Draconis	11 32.2	+67 53	8.9— 9.6	0 16.0	5 23; 12 14; 19 4; 25 19
S Muscae	12 07.4	−69 36	6.5— 7.3	9 15.8	6 7; 15 22; 25 14
SU Draconis	12.8	+70 04	8.8— 9.6	0 13.7	1 23; 9 22; 17 22; 25 21
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	3 15; 10 9; 23 20; 30 13
R Crucis	18.1	−61 04	6.8— 8.0	5 19.8	1 6; 12 22; 24 14; 30 9
S Crucis	48.4	−57 53	6.6— 7.8	4 16.6	4 4; 13 13; 22 22; 27 15
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	4 19; 12 7; 19 19; 27 7
W Virginis	13 20.9	− 2 52	8·7—10.4	17 06.5	8 13; 25 20
RV Ursae Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	6 14; 13 14; 20 15; 27 15
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	5 19; 14 0; 22 5
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	1 15; 14 15; 24 14; 30 2
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	7 7; 14 20; 22 9; 29 22
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	7 12; 14 21; 22 7; 29 17
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	3 16; 10 10; 24 0; 30 18
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	4 19; 11 3; 23 19; 30 3
S Normae	16 10.6	−57 39	6.5— 7.4	9 18.1	6 5; 15 23; 25 17
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	4 4; 13 1; 21 21; 30 18
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	5 7; 11 9; 23 12; 29 13
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	2 5; 9 5; 23 5; 30 6
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	6 10; 23 13
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	3 3; 10 17; 18 7; 25 21
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	1 14; 13 3; 24 17; 30 11
U Sagittarii	18 26.0	−19 12	6.5— 7.3	6 17.9	7 5; 13 23; 20 16; 27 10
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	9 9; 19 17; 30 1
Y Lyrae	34.2	+43 52	11.3—12.3	0 12.1	3 13; 9 14; 21 15; 27 16
RZ Lyrae	39.9	+32 42	9.9—11.2	0 12.3	3 17; 9 20; 22 3; 28 6
RT Scuti	44.1	−10 30	9.1— 9.7	0 11.9	4 19; 10 17; 22 15; 28 14
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	1 16; 10 18; 19 20; 28 23
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	7 12; 14 12; 21 13; 28 13
XZ Cygni	30.4	+56 10	8.7— 9.3	0 11.2	4 12; 11 12; 18 12; 25 12
U Vulpec.	32.2	+20 07	6.9— 7.6	7 23.5	2 23; 10 22; 18 22; 26 21
SU Cygni	40.8	+29 01	6.6— 7.4	3 20.3	6 2; 13 19; 21 11; 29 4
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	3 11; 10 15; 18 19; 25 23
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	4 12; 12 21; 21 6; 29 16
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	3 4; 9 12; 22 3; 28 11
XX Cygni	20 01.3	+58 40	10.5—11.5	0 03.2	4 23; 11 17; 18 11; 25 5
V Vulpec.					6 21
X Cygni	39.5	+35 14	6.0— 7.0	16 09.3	4 21; 21 7
T Vulpec.	47.2	+27 52	5.5— 6.5	4 10.5	3 16; 12 13; 21 10; 30 7
WY Cygni	52.3	+30 03	9.5—10.3	0 13.5	5 1; 11 18; 18 12; 25 5
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	6 13; 13 6; 19 23; 26 16
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	10 5; 24 23
VY Cygni	21 00.4	+39 34	8.9— 9.5	7 20.6	4 8; 12 5; 20 1; 27 22
VZ Cygni	21 47.7	+42 40	8.4— 9.2	4 20.7	2 16; 12 24; 22 3; 27 0
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	6 13; 15 4; 23 20
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	4 4; 9 13; 20 6; 25 15
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	3 12; 14 9; 25 6
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	3 22; 10 8; 23 4; 29 14
V Lacertae	22 44.5	+55 48	8.2— 8.9	4 23.6	1 11; 11 10; 21 9; 26 9
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	6 9; 11 19; 22 16; 28 3
RS Cassiop.	32.6	+61 52	9.1—10.0	6 07.1	1 13; 7 20; 20 10; 26 17
RY Cassiop.	47.2	+58 11	9.2—10.0	12 03.4	9 20; 21 23;
U Pegasi	23 52.9	+15 24	9.3— 9.9	0 04.5	2 11; 9 23; 17 10; 24 22

Observations of Nova (2) Geminorum.—Following are my observations of Nova (2) Geminorum from 1913 March 11 to April 10. Telescope, 4-inch equatorial refractor.

OBSERVATIONS OF NOVA (2) GEMINORUM

1913 Mar. 11–Apr. 10.

Date	Mag.	Color	Comparison Stars
Mar. 11	8.4	Very light bluish green	BD.+32° 1442 and 1447
Mar. 14	8.3	Very light bluish green	BD.+32° 1442 and 1447
Mar. 17	8.4	Light bluish green	BD.+32° 1442 and 1447
Mar. 18	8.5	Rather light bluish green	BD.+32° 1442 and 1447
Mar. 28	8.3	Rather light bluish green	BD.+32° 1442 and 1447
Mar. 29	8.3	Light bluish green	BD.+32° 1442 and 1447
Mat. 31	8.6	Rather light bluish green	BD.+32° 1434, 1442, 1447
Apr. 5	8.4	Light bluish green	BD.+32° 1442 and 1447
Apr. 6	8.4	Light bluish green	BD.+32° 1434, 1442, 1447
Apr. 7	8.6	Light bluish green	BD.+32° 1434, 1442, 1447
Apr. 10	8.4	Light bluish green	BD.+32° 1434, 1442, 1447

Extended unpropitious weather, as in the case of the few preceding months, has prevented more observations of the Nova during the past four weeks.

The Nova has continued to be fairly at rest, as is apparent from the foregoing table, throughout the course of the present set of observations (*cf.* those published in *P. A.* for April 1913, No. 204, p. 238). It has never gone above magnitude 8.3, and on two nights (March 31 and April 7) was as low as the 8.6 magnitude—a range of less than 0.3 magnitude. The color too for the most part has remained practically the same, but lately it has had a slight tendency to increase somewhat in depth, according to my estimates, having passed from a *very* light bluish green to simply a *light* bluish green hue. The variations in color of the Nova seem to me to be almost as important as its fluctuations in magnitude, for the two phenomena are doubtless intimately physically connected.

FREDERICK C. LEONARD.

1338 Madison Park, Chicago, Ill.,
1913 April 12.

COMET AND ASTEROID NOTES.

Ephemeris of Comet 1912 *a* (Gale).

[From *Astronomische Nachrichten* No. 4639.]

1913	True α h m s	True δ ° ′	log *r*	log Δ	Brightness
April 30	6 25 05	+49 16.8	0.5170	0.5683	12.2
May 1	26 26	49 05.9			
2	27 46	48 55.1			
3	29 06	48 44.4			
4	30 25	48 33.9			
5	31 44	48 23.5			
6	33 03	48 13.3			
7	34 22	48 03.2			
8	6 35 41	+47 53.2	0.5293	0.5898	12.3

According to an observation at Bothkamp on March 12, the correction to the ephemeris was then $+2^s$ and $-2.'2$. The nucleus was almost star-like and of about magnitude 11.5. The diameter of the coma was 2′ to 3′. The comet may still be visible with telescopes of moderate power.

Ephemeris of Asteroid MT for the Opposition of 1915.—The enclosed figures I am sending you in relation to MT are based upon elements by Tolnay in *Astronomische Nachrichten* 4607, and also on page 450 of the December 1912 *Observatory*. They are the best elements published so far, as they are based upon more photographic positions than any others. There will be no hope of picking the asteroid up at the next opposition, of March this year, as it will be 19.5 magnitude, according to Mr. A. C. D. Crommelin. If Tolnay's elements are correct the inclosed ephemeris for April 28 to Oct. 5, 1915 and constants are correct, as I have checked and cross checked them by every formula I know of.

1915		α			δ			log r	log Δ
		h	m	s	°	′	″		
April	28	16	10	30	— 6	59	39	0.33348	0.08370
May	6	16	5	1	— 5	26	58	0.32264	0.05270
	14	15	57	42	— 3	50	42	0.31142	0.02538
	22	15	48	56	— 2	16	54	0.29978	0.00293
	30	15	39	29	— 0	51	44	0.28774	9.98614
June	7	15	30	9	+ 0	18	55	0.27530	9.97513
	15	15	21	46	+ 1	9	49	0.26244	9.96959
	23	15	15	8	+ 1	38	25	0.24920	9.96858
July	1	15	10	7	+ 1	44	0	0.23558	9.97100
	9	15	9	3	+ 1	27	53	0.22164	9.97558
	17	15	10	4	+ 0	54	14	0.20740	9.98125
	25	15	13	56	— 0	0	24	0.19296	9.98703
Aug.	2	15	20	27	— 1	7	17	0.17842	9.99238
	10	15	29	37	— 2	26	7	0.16390	9.99678
	18	15	41	23	— 3	54	37	0.14958	0.00000
	26	15	55	38	— 5	30	30	0.13568	0.00190
Sept.	3	16	12	22	— 7	11	23	0.12244	0.00248
	11	16	31	34	— 8	55	7	0.11016	0.00204
	19	16	53	17	—10	38	47	0.09920	0.00074
	27	17	17	30	—12	19	1	0.08988	9.99900
Oct.	5	17	44	11	—13	51	55	0.08256	9.99746

$$x = r\,(9.99993)\,\sin\,(275^\circ\ 26'\ 43''.40 + v)$$
$$y = r\,(9.98929)\,\sin\,(185\ \ 12\ \ 41\ \ .90 + v)$$
$$z = r\,(9.34258)\,\sin\,(190\ \ \ 3\ \ 40\ \ .40 + v)$$

Opposition May 22, 1915. Perihelion Oct. 25, 1915.

F. E. SEAGRAVE.

Cambridge, Mass., Jan. 24, 1913.

The Asteroid (52) Europa.—The ephemeris of this asteroid given in our last number is considerably in error. The asteroid was found by means of a photograph taken with the six-inch doublet at Goodsell Observatory on the night of April 11 with an exposure of an hour. Its position was then about 6^m west and 32′ north of the predicted place. It is following approximately the course laid down upon the chart but is eight days ahead of its schedule. To find the asteroid by the aid of the chart add eight days to the date of observation and look about 5′ south of the place marked on the chart for the later date.

A mistake was made in marking the declination on the margin of the chart, that for the epoch 1855 having been written instead of that for 1913. The right ascension is for 1913; 18′ should be added to the chart declination to give that for 1913.

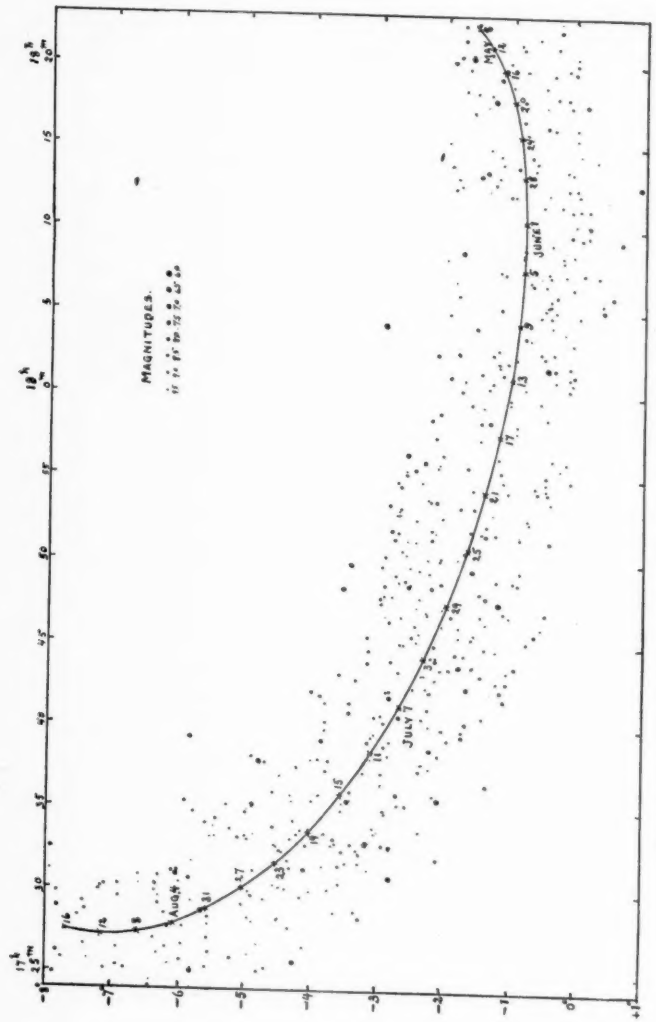


CHART OF THE ASTEROID (354) ELEONORA FROM MAY 8 TO AUGUST 16, 1913.

Chart of the Asteroid (354) Eleonora.—The accompanying chart shows the computed path of the asteroid (354) Eleonora among the stars from May 8 to August 16, 1913. The asteroid will be at opposition on June 20. At that time its computed brightness is equal to that of a star of magnitude 10.3, so that it is within reach of small telescopes.

The chart was prepared from an ephemeris calculated by A. Antionazzi, and published in *Memorie della Società degli Spettroscopisti Italiani* for February 1913.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, Mar.-Apr., 1913.—In a monthly report of nearly a thousand observations it is gratifying to note the continued progress of the Association. Dr. Gray's splendid list of 202 observations helped out materially, and attests the great service he is rendering. Dr. Gray has lately joined the B. A. A. and coöperates in the work of its variable star section. Messrs. Ginori and Lacchini are also members of this section.

It is a pleasure to announce a new member of our Association, Mr. J. H. H. Burbank, of Lynn, Mass. Mr. Burbank observes with a three-inch refractor, and his observations will be indicated in the reports by the abbreviation "Bk."

The members of the Association will, I am sure, sympathize with Mr. Otto Mach, of Dayton, Ohio, one of our members, in the loss of the mirror of his reflector. The day before the disaster he had sent it to a local firm to be resilvered, and their building was completely wrecked by the flood. Mr. Mach has made a very good start in observing variables, and it is hoped that he will be able to resume the work in the near future.

The Annual Report of the director of the Astronomical Observatory of Harvard College, for the year ending September 30, 1912, has recently been published, and contains the detailed enumeration of observations by individual variable star observers. It is interesting to note the great increase in the number of observations contributed. Last year 2532 observations were received; this year 8443. Of our members, Mr. Jacobs leads with a total of 1163 observations. I take the liberty of quoting the following excerpt from Professor Pickering's report: "The important aims are to secure observations, at short intervals, of the principal variables of long period, and to obtain useful results from large numbers of owners of small telescopes whose work otherwise might be of little value. Both of these conditions seem now to be fulfilled in a highly satisfactory manner."

An inspection of observations sent in this month reveals many interesting features.

The variable, 213843 SS Cygni, rose suddenly in its characteristic manner during the second week in March, and was observed at maximum by five observers. The light curve of this interesting variable for the year 1912 has been drawn for us by Mr. H. C. Bancroft, Jr., and forms a part of this report. Mr. Bancroft deserves great credit for the care and skill displayed in the drawing. The secretary also received from Mr. Burbeck an exceedingly well executed curve of this variable. It is a pleasure to note in such ways the enthusiasm and interest that is being taken in the work by the members of the Association.

VARIABLE STAR OBSERVATIONS Mar.–Apr., 1913.

001755
T Cassiop.

Mo.	Day	Est.	Obs.
3	8	11.2	Ba
	11	11.3	Y
4	1	12.0	J
	1	11.6	Y

001838
R Androm.

Mo.	Day	Est.	Obs.
3	1	7.0	L
	4	6.9	L
	4	7.0	L
	11	7.1	L

003179
Y Cephei

Mo.	Day	Est.	Obs.
3	31	10.5	G

004132
RW Androm.

Mo.	Day	Est.	Obs.
3	16	8.3	J

004958
W Cassiop.

Mo.	Day	Est.	Obs.
3	11	9.7	J
	16	9.8	J
	20	9.7	J
	29	9.6	J
	31	9.6	J

005381
U Cephei

Mo.	Day	Est.	Obs.
3	6	8.4	G
	6	9.1	G
	7	7.2	G
	7	7.1	G
	26	9.1	G
	31	8.8	G

013238
RU Androm.

Mo.	Day	Est.	Obs.
3	11	10.3	J
	16	10.1	J
	20	10.2	J
	22	10.3	J
	31	10.4	J

013338
Y Androm.

Mo.	Day	Est.	Obs.
3	31	11.7	J

014958
X Cassiop.

Mo.	Day	Est.	Obs.
3	7	11.3	L

021024
R Arietis

Mo.	Day	Est.	Obs.
3	8	8.0	Ba

021143a
W Androm.

Mo.	Day	Est.	Obs.
3	5	11.4	F

021258
T Persei

Mo.	Day	Est.	Obs.
3	8	8.7	Ba
	11	8.7	Ba
	24	8.7	Ba

021403
o Ceti

Mo.	Day	Est.	Obs.
2	24	5.8	L
	25	6.4	Gi
3	1	5.5	L
	2	5.8	Bu
	2	5.5	L
	3	5.8	Gi
	4	5.5	L
	5	5.6	F
	7	5.2	L
	9	5.5	Bu
	11	5.7	G
	11	5.1	L
	22	5.2	Bu
	23	5.2	Bu
	29	4.8	Bu
4	1	5.0	Bu

021558
S Persei

Mo.	Day	Est.	Obs.
3	8	8.0	Ba
	11	8.0	Ba
	24	8.6	G
	24	8.0	Ba
	28	8.1	B
	31	9.2	G
4	5	8.2	B

023133
R Trianguli

Mo.	Day	Est.	Obs.
3	2	6.8	G
	17	5.6	Y
4	1	5.6	Y

024356
W Persei

Mo.	Day	Est.	Obs.
3	8	9.3	Le
	11	9.5	V
	11	9.3	Ba
	12	9.2	Hu
	16	9.3	Le
	17	9.5	Le
	18	9.5	Le
	24	10.0	G
	29	9.2	Ba
	29	9.6	Le
	31	10.3	G
	31	9.4	Le
4	5	9.5	Le
	6	9.7	V
	8	9.8	O

030514
U Arietis

Mo.	Day	Est.	Obs.
3	17	8.9	Y

031401
X Ceti

Mo.	Day	Est.	Obs.
3	5	11.5	F

032043
Y Persei

Mo.	Day	Est.	Obs.
3	5	9.8	F
	8	9.6	Ba
	11	9.8	Ba
	12	9.4	Hu
	24	10.1	Ba
	28	10.2	B
	29	10.4	Ba
	29	10.3	F
	29	10.3	O
4	5	10.0	B

033362
U Camelop.

Mo.	Day	Est.	Obs.
3	3	8.5	G
	6	7.6	G
4	8	8.5	O

042215
W Tauri

Mo.	Day	Est.	Obs.
3	6	10.2	G
	11	9.8	Y
	11	10.0	G
	23	9.8	G
	24	9.8	O
	28	9.2	Ba
	29	9.6	O
	29	9.5	G
4	1	9.5	O
	1	9.5	Y
	1	9.5	G

043065
T Camelop.

Mo.	Day	Est.	Obs.
3	11	8.9	Y
	19	8.7	Y
4	2	8.5	Y

043208
RX Tauri

Mo.	Day	Est.	Obs.
3	3	10.7	Gi
	11	10.3	Gi

043274
X Camelop.

Mo.	Day	Est.	Obs.
3	3	8.7	G
	11	8.7	Y
	19	9.6	Y
	24	9.5	G
	24	10.0	O
	26	9.9	G
	28	10.8	O
	29	10.4	Ba
	31	10.9	Ba
	31	10.3	G
4	2	11.3	O
	2	11.2	Y

045307
R Orionis

Mo.	Day	Est.	Obs.
3	19	9.4	Y
4	1	9.8	Y

045514
R Leporis

Mo.	Day	Est.	Obs.
2	24	7.8	L
3	1	8.3	L
	2	7.2	Bu
	3	7.4	Gi
	4	7.5	L
	5	7.2	F
	6	7.3	G
	7	7.8	L
	8	7.2	Ba
	8	7.6	Le
	9	7.4	Bu
	9	8.1	V
	9	7.0	Ha
	11	7.5	L
	12	7.2	B
	14	7.2	G
	16	7.7	Le
	18	7.8	Le
	19	7.3	B
	19	8.3	L
	22	7.4	Bu
	23	7.2	Bu
	23	7.2	G
	26	7.0	F
	29	7.4	Bu
	29	7.7	B
	30	7.3	G
	30	7.3	Ba
4	1	7.4	Bu

050003
V Orionis

Mo.	Day	Est.	Obs.
3	2	9.6	G
	11	10.0	G
	19	10.8	Y
4	1	11.4	Y

050953
R Aurigae

Mo.	Day	Est.	Obs.
3	5	11.0	F
	11	11.5	J
	11	11.6	B
	19	11.6	Y
	19	11.6	B
	22	11.6	J
	28	12.3	B
	31	12.2	J
4	2	11.6	Y
	5	12.3	B

052034
S Aurigae

Mo.	Day	Est.	Obs.
2	25	9.3	L
3	5	9.0	F
	11	9.0	Y
	24	9.0	Y
	26	8.5	F
4	3	9.0	Y

052036
W Aurigae

Mo.	Day	Est.	Obs.
3	8	12.1	Ba
	29	10.4	O
	30	9.9	Ba
4	1	10.2	O
	5	9.9	V
	7	10.1	O
	9	9.3	O

053068
S Camelop.

Mo.	Day	Est.	Obs.
3	11	8.7	Y
	24	8.9	Y
4	2	9.0	Y

053531
U Aurigae

Mo.	Day	Est.	Obs.
3	11	10.6	Y
	24	9.6	Y
4	2	8.6	Y

054319
SU Tauri

Mo.	Day	Est.	Obs.
3	11	9.6	Y
4	2	9.7	Y

054920
U Orionis

Mo.	Day	Est.	Obs.
3	3	10.7	Gi
	5	10.8	F
	12	11.0	Hu
	17	10.9	Hu
	24	10.7	Y
	26	10.5	F
	28	10.9	Hu
	29	10.5	O
4	6	9.9	Hu

054974
V Camelop.

Mo.	Day	Est.	Obs.
3	3	9.9	G
	24	10.0	O
	26	9.5	G
	28	10.0	O
	29	9.5	Ba
	31	9.8	Ba
	31	9.4	G
4	2	10.0	O
	5	10.8	Ba
	8	10.5	O

055353
Z Aurigae

Mo.	Day	Est.	Obs.
3	19	9.6	Y
4	2	10.2	Y

060124
S Leporis

Mo.	Day	Est.	Obs.
3	30	6.5	G

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061702
V Monoc.

Mo.	Day	Est.	Obs.
3	5	8.5	G
	11	7.7	V
	13	7.7	G
	23	7.7	G
	27	7.6	G
	29	7.7	G
4	6	7.6	V

062808
Z Monoc.

Mo.	Day	Est.	Obs.
3	5	8.6	G
	13	8.6	F
	29	8.4	G

063159
U Lyncis

Mo.	Day	Est.	Obs.
3	8	10.7	Ba
	11	10.8	Ba
	24	11.2	Ba
	28	11.4	Ba
	30	11.5	Ba
	31	11.5	Ba
4	1	11.0	O
	5	11.4	Ba
	7	11.3	O
	7	11.6	Ba

063558
S Lyncis

Mo.	Day	Est.	Obs.
3	30	13.8	Ba

064932
NOVA GEMIN. 2

Mo.	Day	Est.	Obs.
2	24	8.2	L
3	1	8.5	L
	2	8.4	Bu
	3	9.2	Gi
	4	8.3	L
	4	8.4	G
	6	8.4	G
	7	8.5	L
	9	8.4	Bu
	9	8.3	V
	11	8.5	L
	11	9.3	Gi
	11	8.8	Y
	11	8.4	V
	19	8.6	L
	19	8.5	M
	19	8.7	Y
	22	8.2	Bu
	23	8.4	Bu
	24	8.6	O
	25	8.5	C
	26	8.5	C
	27	8.5	G
	28	8.8	M
	28	8.7	O
	29	8.6	C

NOVA GEMIN. 2

Mo.	Day	Est.	Obs.
3	29	8.4	Bu
	29	8.6	G
	30	8.8	G
	31	8.7	Ba
	31	8.8	G
	31	8.8	M
4	1	8.6	O
	1	8.5	Bu
	1	8.9	G
	4	8.5	Ha
	5	8.9	M
	5	8.6	V
	7	8.8	O
	9	8.7	O

065208
X Monoc.

Mo.	Day	Est.	Obs.
3	2	7.6	G
	5	8.3	G
	5	8.1	F
	8	8.1	G
	11	8.1	G
	23	7.8	G
	27	8.4	G
	29	8.4	G

065355
R Lyncis

Mo.	Day	Est.	Obs.
3	2	9.0	Bu
	8	8.6	Ba
	9	8.8	Bu
	11	8.9	J
	11	8.5	B
	17	9.1	Y
	19	8.5	B
	22	8.8	Bu
	22	9.1	J
	23	9.0	Bu
	24	9.3	Y
	29	9.3	J
	29	9.2	Bu
	29	8.9	B
	30	8.8	G
	30	9.1	Ba
	31	9.5	J
4	1	8.6	Bu
	2	9.4	O
	3	9.3	Y
	5	9.0	B
	7	9.4	O
	8	9.4	O
	9	9.3	O

070122a
R Geminorum.

Mo.	Day	Est.	Obs.
3	12	12.1	Hu
	28	13.5	Hu
4	5	13.6	Ba

070310
R Can. Min.

Mo.	Day	Est.	Obs.
2	25	9.6	L
3	1	9.8	L
	2	10.0	G
	5	10.5	G
	7	10.0	L
	11	9.6	Ba
	11	10.2	V
	29	10.4	Ba
	30	10.4	G
4	6	10.6	V

071044
L^2 Puppis

Mo.	Day	Est.	Obs.
3	5	3.5	F
	26	4.0	F

072708
S Can. Min.

Mo.	Day	Est.	Obs.
2	24	8.2	L
3	1	8.0	L
	2	8.0	G
	2	7.8	Bu
	4	7.9	L
	5	8.1	F
	6	8.0	G
	7	7.9	L
	7	7.6	B
	8	7.6	Ba
	8	7.7	Ma
	8	8.0	G
	9	8.1	Ha
	9	7.8	Bu
	11	7.9	G
	11	7.8	L
	12	7.1	B
	12	8.0	O
	14	7.6	Ma
	15	7.9	M
	16	7.7	Ha
	17	7.8	S
	19	7.8	B
	19	8.0	M
	19	7.4	L
	22	7.6	Bu
	23	7.7	G
	23	7.8	Bu
	24	7.9	O
	24	7.5	Ba
	26	7.4	F
	27	7.8	G
	28	7.6	B
	28	8.0	O
	28	7.8	M
	29	7.6	G
	29	7.6	Bu
	30	7.5	Ha
	30	7.4	Ba
	31	8.0	M

S Can. Min.

Mo.	Day	Est.	Obs.
4	1	8.0	O
	1	8.0	Bu
	1	7.8	S
	2	7.8	B
	4	7.7	Ha
	5	8.1	M
	7	8.0	O
	9	7.7	O

073508
U Can. Min.

Mo.	Day	Est.	Obs.
3	11	13.0	Y
4	2	12.9	Y
	7	12.7	Ba

074922
U Geminorum

Mo.	Day	Est.	Obs.
3	12	11.0	Hu
	28	10.9	Hu
4	5	11.3	B

075548
V Puppis

Mo.	Day	Est.	Obs.
3	5	5.0	F
	26	5.0	F

081112
R Cancri

Mo.	Day	Est.	Obs.
2	25	10.0	L
3	1	9.8	L
	4	9.4	L
	7	9.6	L
	8	9.6	Ba
	11	9.5	V
	11	9.0	L
	12	9.6	Hu
	24	9.3	O
	28	9.0	Ba
	28	9.5	O
	28	9.6	Hu
4	1	9.4	O
	5	9.1	V
	7	9.3	O
	7	8.7	Ba
	9	8.9	O

081617
V Cancri

Mo.	Day	Est.	Obs.
3	2	8.3	G
	3	7.9	Gi
	11	8.0	Gi
	24	8.5	O
	28	8.6	O
	31	7.8	G
4	1	8.8	O
	7	8.8	O
	9	8.9	O

081633
T Lyncis

Mo.	Day	Est.	Obs.
3	2	10.0	G
	3	9.8	G
	5	13.5	Ba
	5	9.5	G
	5	9.4	G
	7	9.5	G
	11	9.8	G
	13	11.4	F
	13	9.5	G
	14	9.2	G
	23	8.6	G
	29	9.8	G
	30	10.0	G
	31	10.4	G
4	1	10.5	G

082405
RT Hydrae

Mo.	Day	Est.	Obs.
2	25	9.2	L
3	7	9.0	L
	8	8.7	Ba
	11	8.9	V
	28	8.0	Ba
	29	8.2	O
4	1	8.0	O
	6	8.0	V

084803
S Hydrae

Mo.	Day	Est.	Obs.
3	8	8.3	Ba
	12	8.5	Hu
	12	8.2	B
	13	8.8	G
	24	8.9	G
	24	9.1	O
	28	8.2	Hu
	28	8.9	Ba
	28	9.2	O
	29	9.0	B
	31	9.1	G
4	1	9.6	O
	5	9.4	B
	7	9.6	O
	9	10.1	O

085120
T Cancri

Mo.	Day	Est.	Obs.
2	25	9.0	L
3	1	8.9	L
	3	8.2	Gi
	7	9.1	L
	8	8.2	Ba
	9	8.6	V
	11	8.3	Gi
	12	8.1	B
	12	8.2	Hu
	24	9.0	O
	26	9.5	G
	28	8.4	Ba

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T Cancri

Mo.	Day	Est.	Obs.
	28	8.2	Hu
	29	8.4	B
4	5	9.1	V

090425
W Cancri

4	1	8.3	S

093178
Y Draconis

4	2	12.9	Y

093934
R Leo. Min.

3	2	8.0	G
	5	8.1	G
	5	8.2	G
	8	8.3	Ma
	11	8.5	Ma
	11	8.6	G
	15	8.6	G
4	17	7.9	Hu
	23	9.2	G
	28	8.2	Hu

094211
R Leonis

2	24	6.7	L
	25	6.5	L
3	1	6.6	L
	2	6.6	G
	2	6.7	Bu
	2	6.5	L
	3	6.7	Gi
	3	6.6	L
	5	6.5	G
	5	6.6	L
	7	6.4	L
	7	6.5	B
	8	6.2	G
	8	6.7	Le
	8	6.8	Ma
	8	6.4	Ba
	9	6.7	Bu
	9	7.0	V
	9	6.6	Ha
	11	6.3	L
	11	6.1	G
	11	7.0	Y
	11	6.8	Gi
	11	6.5	Le
	11	6.8	Ma
12	6.5	O	
12	6.5	B	
14	6.6	Ma	
14	6.6	Le	
15	6.2	G	
16	6.4	Ha	

R Leporis

Mo.	Day	Est.	Obs.
3	17	6.6	S
	17	6.7	Le
	18	6.8	Le
	19	6.5	B
	19	6.6	L
	22	6.4	Bu
	23	6.4	Bu
	23	6.0	G
	24	6.5	O
	24	7.0	Y
	25	7.3	C
	28	6.4	Ba
	28	6.6	B
	28	6.9	O
	29	6.9	Le
	29	7.2	C
	29	6.5	Bu
	29	6.2	G
	30	6.3	Ha
	31	7.0	Le
	31	5.8	G
	1	6.6	O
	1	6.6	Bu
	1	6.7	S
	3	6.8	Y
	4	6.2	Ha
	5	6.5	B
	5	6.9	Le
	5	6.8	V
	7	6.9	O

094622
Y Hydrae

3	7	6.3	G
	11	6.3	G
	13	6.5	G
	24	6.6	G
	27	6.6	G

103212
U Hydrae

3	24	4.5	G
	25	4.2	C
	26	4.3	C
	29	4.8	G
	29	4.5	C

103769
R Urs. Maj.

3	11	11.8	B
	28	12.1	B
	29	12.2	M
	31	12.1	J
	2	12.1	B
	4	11.8	Ha
	7	13.0	Ba

104620
V Hydrae

Mo.	Day	Est.	Obs.
3	6	6.5	G
	7	6.5	G
	11	6.4	G
	13	6.5	F
	13	6.3	G
	24	6.3	G
	29	6.2	G
4	1	6.5	G

105517
R Crateris

3	5	9.0	G
	6	9.2	G
	7	9.0	G
	11	8.8	G
	11	8.8	G
	13	8.6	G
	24	8.8	G
	29	8.3	G
4	1	8.5	G

110506
S Leonis

3	11	12.2	Y
	24	12.0	Y
4	5	11.5	Y

122001
SS Virginis

3	5	6.7	G
	8	7.0	G
	11	6.8	G
	28	7.9	Hu
	28	6.6	O
	29	7.4	Ba
4	1	7.0	G
	7	7.2	O
	8	7.2	O

122532
T Can. Ven.

3	11	9.2	Y
	24	9.1	Y
4	5	8.9	Y
	6	9.5	V

123160
T Urs. Maj.

2	25	11.2	L
3	1	10.8	L
	7	11.7	L
	8	11.8	Ba
	8	11.4	Le
	11	11.8	Ba
	11	11.6	B
	11	12.0	Y
	11	10.5	G
	24	12.2	Y
	24	12.4	Ba
	28	12.3	B

T Urs. Maj.

Mo.	Day	Est.	Obs.
	28	12.3	Ba
	29	13.0	M
	30	12.5	Ba
	31	12.6	Ba
4	1	12.3	B
	2	12.4	Y
	5	12.5	B
	6	12.6	Ba

123307
R Virginis

3	28	6.9	O
	28	6.5	Hu
4	1	6.9	O
	1	7.6	S
	5	7.0	Ba
	7	6.9	O

123961
S Urs. Maj.

3	1	8.7	L
	2	9.2	Bu
	5	8.6	G
	5	8.9	F
	5	9.0	L
	8	8.8	G
	8	9.0	Ba
	8	9.6	Le
	8	9.2	Ma
	9	9.2	Bu
	9	9.2	Ha
	11	9.4	Y
	11	9.1	B
	11	9.5	Ma
	11	9.6	Le
	11	9.2	Gi
	11	9.2	Ba
	11	8.9	G
	12	9.7	S
	12	9.5	J
	14	9.5	Ma
	14	9.6	M
	14	9.7	Le
	14	9.4	G
	16	9.4	Ha
	16	9.7	Le
	17	9.8	J
	17	9.7	Le
	18	9.7	Le
	19	9.4	L
	19	9.8	M
	20	9.9	J
	22	9.4	B
	22	9.5	Bu
	23	9.6	Bu
	23	10.5	G
	24	10.2	O
	24	10.0	Y
	24	9.9	Ba
	26	10.3	F

S Urs Maj.

Mo.	Day	Est.	Obs.
	26	10.6	G
	28	10.0	B
	28	10.7	M
	28	10.7	Ba
	29	10.8	M
	29	9.6	Bu
	29	10.6	G
	29	10.4	J
	29	10.5	J
	30	9.9	Ha
	30	10.4	Ba
	31	10.5	J
	31	11.0	G
	31	10.4	Le
	31	10.8	M
	31	10.6	Ba
4	1	9.8	Bu
	1	10.4	B
	1	10.6	S
	1	10.6	J
	2	10.6	O
	2	10.5	J
	4	10.4	Ha
	5	10.3	B
	5	10.6	M
	5	10.8	Le
	6	10.9	V
	6	10.6	Ba
	6	9.7	Hu
	9	10.7	O

124204
RU Virginis

3	28	9.0	Hu
4	6	9.1	Ba
	7	9.6	O
	8	9.5	O

124606
U Virginis

4	1	10.1	S

132422
R Hydrae

3	1	4.4	L
	3	4.6	L
	3	4.8	Gi
	5	4.8	G
	5	4.7	L
	11	4.9	L
	11	4.9	G
	11	5.0	Gi
	13	4.8	G
	13	4.9	L
	15	4.5	F
	15	4.9	G
	22	5.1	G
	26	5.3	G
	29	5.3	G

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132706
S Virginis

Mo.	Day	Est.	Obs.
3	1	8.6	L
	3	8.6	L
	11	9.0	L

133633
T Centauri

Mo.	Day	Est.	Obs.
3	11	8.0	G

134440
R Can. Ven.

Mo.	Day	Est.	Obs.
2	25	11.2	L
3	2	10.4	L
	4	10.2	L
	7	10.0	L
	8	9.6	Ba
	11	9.5	Ba
	11	9.6	L
	12	9.3	B
	14	10.2	M
	17	9.1	B
	18	9.7	M
	19	9.1	L
	22	8.7	B
	28	8.6	Ba
	28	8.5	B
	28	8.9	M
	29	8.5	O
	31	8.7	M
4	1	8.6	O
	1	8.5	B
	5	9.4	Ba
	5	8.5	B
	5	8.3	M
	7	8.5	O
	9	8.4	O

141567
U Urs. Min.

Mo.	Day	Est.	Obs.
3	12	9.1	J
	12	8.4	S
	17	9.1	J
	20	8.7	J
	22	8.8	J
	29	9.1	J
	29	9.0	J
	30	8.7	Ba
	31	9.1	J
4	1	8.9	J
	6	8.6	Ba

141954
S Boötis

Mo.	Day	Est.	Obs.
3	7	12.4	B
	11	13.2	Ba
	28	12.6	B
4	1	12.2	B

142539
V Boötis

Mo.	Day	Est.	Obs.
3	3	8.8	Gi
	4	9.0	L
	5	8.9	G
	7	9.1	G
	7	9.2	L
	11	9.3	L
	11	9.3	Gi
	11	9.0	G
	12	9.4	S
	14	9.3	G
	17	9.2	B
	24	9.7	G
	28	10.2	O
	28	9.7	B
	29	9.7	G
	31	10.0	G
4	1	10.1	O
	5	9.9	B
	5	10.0	M
	7	10.4	O

142584
R Camelop.

Mo.	Day	Est.	Obs.
2	25	11.0	L
3	1	10.9	L
	7	10.5	L
	11	10.2	B
	11	10.0	L
	17	9.9	B
	24	9.2	O
	28	9.1	O
	28	9.0	B
	29	9.2	J
	31	9.1	J
4	1	8.8	O
	1	8.7	B
	5	8.6	B
	7	8.7	O
	8	8.5	O

143227
R Boötis

Mo.	Day	Est.	Obs.
3	3	12.6	Gi
	5	12.0	L
	11	11.6	B
	17	11.7	B

150605
Y Librae

Mo.	Day	Est.	Obs.
3	1	9.4	L
	3	9.7	L
	5	9.7	L
	11	9.7	L

151520
S Librae

Mo.	Day	Est.	Obs.
3	30	9.4	Ba

151731
S Cor. Bor.

Mo.	Day	Est.	Obs.
3	3	7.9	L
	5	7.6	G
	11	7.7	Ba
	13	7.8	G
	28	7.9	Ba
4	1	8.5	O
	7	8.3	Ba
	8	8.5	O

151822
RS Librae

Mo.	Day	Est.	Obs.
3	30	10.2	Ba

153215
W Librae

Mo.	Day	Est.	Obs.
3	3	11.9	L

153378
S Urs. Min.

Mo.	Day	Est.	Obs.
2	25	11.1	L
3	1	11.7	L
	5	11.3	F
	5	11.7	L
	11	11.2	Gi

154428
R Cor. Bor.

Mo.	Day	Est.	Obs.
3	1	6.0	L
	3	6.0	L
	3	6.0	Gi
	5	5.8	G
	7	5.8	G
	8	5.8	Ba
	11	6.0	L
	11	5.6	Ba
	11	6.0	G
	12	6.2	J
	13	6.0	G
	13	6.0	L
	14	5.5	M
	15	6.0	F
	17	5.8	J
	21	5.4	C
	22	5.9	J
	24	5.8	Ba
	25	5.4	C
	26	6.0	G
	28	6.0	Ba
	28	5.8	O
	29	6.0	G
	29	6.0	J
	29	5.9	J
	29	5.4	C
	30	6.0	Ba
	31	5.8	G
	31	5.8	J
	31	5.2	M
	31	5.8	Ba

R Cor. Bor.

Mo.	Day	Est.	Obs.
4	1	6.0	O
	5	5.0	M
	6	6.0	O
	7	5.8	Ba
	7	6.0	O
	8	6.2	O
	9	6.2	O

154536
X Cor. Bor.

Mo.	Day	Est.	Obs.
3	12	9.3	J
	17	9.3	J
	22	9.1	J
	29	9.1	J
	31	9.2	J

154639
V Cor. Bor.

Mo.	Day	Est.	Obs.
3	5	8.0	G
	7	8.2	G
	13	8.4	G
	27	8.4	G
	29	8.4	G
	31	8.3	G

154615
R Serpentis

Mo.	Day	Est.	Obs.
3	30	7.8	Ba

154736
R Lupi

Mo.	Day	Est.	Obs.
3	5	9.6	G

155823
RZ Scorpii

Mo.	Day	Est.	Obs.
3	7	7.9	G
	11	7.9	G

155847
X Herculis

Mo.	Day	Est.	Obs.
3	3	6.3	L

162119
U Herculis

Mo.	Day	Est.	Obs.
3	5	7.3	G
	7	7.2	G
	13	7.4	G
	15	8.3	F
	16	8.1	M
	30	8.0	Ba
	31	8.4	M
4	5	8.2	B
	6	8.9	M

163137
W Herculis

Mo.	Day	Est.	Obs.
4	5	8.5	Y

163172
R Urs. Min.

Mo.	Day	Est.	Obs.
3	29	10.3	B
4	1	10.0	B
	5	10.0	B
	9	10.3	O

163266
R Draconis

Mo.	Day	Est.	Obs.
4	2	12.2	Y

164715
S Herculis

Mo.	Day	Est.	Obs.
3	17	10.6	J
	29	11.0	J
	31	11.2	J

165030
RR Scorpii

Mo.	Day	Est.	Obs.
3	15	9.5	G

170215
R Ophiuchi

Mo.	Day	Est.	Obs.
3	5	9.2	G
	7	9.6	G
	15	11.4	F
	15	10.0	G

180531
T Herculis

Mo.	Day	Est.	Obs.
3	11	11.7	L
	13	11.5	G
	15	11.2	F
	31	11.2	M

184205
R Scuti

Mo.	Day	Est.	Obs.
3	1	5.2	L
	3	5.0	L
	5	4.8	G
	5	5.1	L
	15	5.5	F
	15	4.8	G

193449
R Cygni

Mo.	Day	Est.	Obs.
3	1	8.2	L
	3	8.4	L
	5	8.7	L
	5	7.5	G
	8	7.5	G
	11	8.5	L
	13	7.4	G
	15	7.5	G
	15	8.4	F
	18	8.5	M
	22	8.4	F
	31	9.0	M

193732
TT Cygni

Mo.	Day	Est.	Obs.
3	11	8.1	G
	15	7.6	F
	22	7.5	F

VARIABLE STAR OBSERVATIONS Mar.–Apr., 1913.—Continued.

194048 RT Cygni

Mo.	Day	Est.	Obs.
3	1	6.7	L
	3	6.7	L
	5	6.7	L
	5	6.5	G
	8	6.9	G
	11	7.1	L
	13	6.7	G
	15	7.5	F
	15	6.8	G
	18	7.4	M
	22	7.3	F
	31	7.9	M

194348 TU Cygni

Mo.	Day	Est.	Obs.
3	8	11.6	G

200647 SV Cygni

Mo.	Day	Est.	Obs.
3	15	9.0	F
	22	8.5	F

200938 RS Cygni

Mo.	Day	Est.	Obs.
3	5	7.5	G
	13	7.1	G
	15	7.1	F
	15	7.1	G
	17	8.5	J
	22	8.3	F
4	1	8.1	J

201008 R Delphini

Mo.	Day	Est.	Obs.
4	1	9.4	J

201647 U Cygni

Mo.	Day	Est.	Obs.
3	1	8.7	L
	5	9.3	L
	5	8.4	G
	11	9.3	L
	13	8.0	G
	15	8.0	F
	15	7.8	G
	17	9.6	J
	22	7.9	F

U Cygni

Mo.	Day	Est.	Obs.
	22	8.0	G
	29	9.4	J
4	1	9.4	J

202539 RW Cygni

Mo.	Day	Est.	Obs.
3	15	8.3	G

202946 SZ Cygni

Mo.	Day	Est.	Obs.
3	15	9.3	F
	22	10.0	F

210868 T Cephei

Mo.	Day	Est.	Obs.
2	25	10.0	L
3	1	9.6	L
	3	9.9	Gi
	5	9.9	L
	8	10.1	Ba
	16	9.9	J
	22	9.5	B
	28	9.7	B
	29	9.9	J
4	1	10.0	J
	2	9.4	B

213244 W Cygni

Mo.	Day	Est.	Obs.
3	1	5.4	L
	3	5.4	L
	11	5.4	L

213678 S Cephei

Mo.	Day	Est.	Obs.
3	8	9.8	Ba
	28	8.9	B
	31	10.3	J
4	1	9.5	B

213843 SS Cygni

Mo.	Day	Est.	Obs.
3	11	8.5	L
	15	8.0	F
	15	8.3	G
	18	8.3	M
	19	8.3	J
	22	9.0	F
4	1	11.6	J

213937 RV Cygni

Mo.	Day	Est.	Obs.
3	15	7.0	F
	15	7.3	G
	19	8.3	J
4	1	7.8	J

230759 V Cassiop.

Mo.	Day	Est.	Obs.
3	5	9.6	F
	9	9.2	V
	16	8.9	J
4	1	8.0	J

235182 V Cephei

Mo.	Day	Est.	Obs.
3	5	6.6	G
	11	6.6	G
	24	6.8	G
	29	6.7	G
	31	6.6	G

235939 SV Androm.

Mo.	Day	Est.	Obs.
3	17	11.0	Y

No. of observations, 975; No. of stars observed, 123; No. of observers, 18.

064932 Nova Geminorum (2) continues to wane steadily, and decreased in brightness, according to our observations, approximately 0.4 of a magnitude during the month.

The variable 023133 R Trianguli, according to Miss Young's observations, has exceeded at its recent maximum its brightest maximum credited by Dr. Hartwig of 5.9.

Three simultaneous observations of 042215 W Tauri were made the night of April 1 with the same result. Seventy observations were secured of the variable 123961 S Ursae Majoris, indicating clearly the value of coöperative observing. The rapid rise of two magnitudes of 142584 R Camelopard is noteworthy.

Dr. Gray included in his list a fine set of observations of the short period variable 005381 U Cephei, showing three minima. The Doctor's zeal and interest in the work is only equalled by his tireless energy.

Dr. Hartwig's calculated maximum of 084803 S Hydrae for April 1 lacked confirmation according to our observations. On that date the variable was approximately 9.5 magnitude and waning.

Dr. Gray observed a maximum of 6.5 magnitude of the variable 194048 RT Cygni March 5. The calculated date of maximum was March 22.

The maximum of the variable 065355 R Lyncis, calculated for March 13, was confirmed by our observations, but the variable fell far short of its high maximum 6.5 magnitude. The brightest estimate sent in was Mr. Bouton's 8.5.

The variable 122001 SS Virginis was at a maximum during March, exceedingly bright and fiery red, which has caused considerable discordance in the estimates.

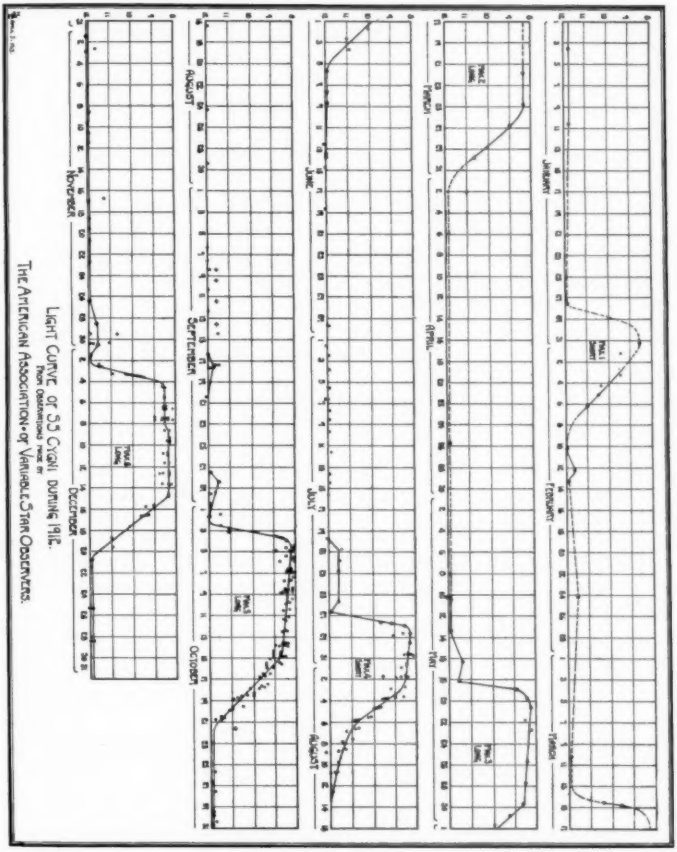
Space does not permit of further comment, but a close perusal of the observations will repay the interested observer.

WM. TYLER OLCOTT
Corresponding Sec'y.

Norwich, Ct., Apr. 10, 1913.

Light Curve of SS Cygni.—The following comments on a comparison of the light curves of 213843 SS Cygni, the result of the observations of the Variable Star Section of the B.A.A.* and the American Association of Variable Star Observers for the year 1912, will be of interest to some of our readers:

The B.A.A. curve shows indecision as regards the second maximum. The A. A. curve would seem to indicate that this maximum was long as credited to this maximum by the B. A. A.



The short outburst preliminary to the long rise appears in both curves, confirming this phenomenon. The A.A. curve notes this decidedly just before the fourth maximum, but lacks confirmation in the B.A.A. curve.

The short dip in the long sixth maximum, December 8, shown in the B.A.A. curve would appear to be confirmed in the A.A. curve.

* See POPULAR ASTRONOMY April 1913, page 237.

On the whole the curves of both Associations are closely in accord. Perhaps the most noticeable feature of the A. A. curve is the increase in the number of observations, manifest especially in the observations of the fifth maximum. This indicates the growth of the A. A. in nine months, which was most gratifying.

The A. A. curve lacks the accuracy of the B. A. A. curve in that in many cases the time of the respective observations is as a rule omitted from the monthly reports of the Association in "POPULAR ASTRONOMY." Hereafter in the case of 213843 SS Cygni, 074922 U Geminorum, and similar erratic variables the time of each observation should be included in the monthly reports sent to the secretary.

The American Association is greatly indebted to Mr. H. C. Bancroft Jr. of West Collingswood, N. J., for his accurate and painstaking sketch of the curve of this wonderful variable. Such work constitutes a valuable addition to the records of the Association, and Mr. Bancroft's zeal in observing, and his willingness to assist in furthering the work of the Association is highly commendable.

WILLIAM TYLER OLCOTT.

The American Meteor Society, Bulletin No. 2.—For the information of members the following tables have been constructed, the first partly from W. F. Denning's results, with some corrections, the second and third copied from 'Das Meteorphänomenen,' by C. Birkenstock. In Table I have been added notes relative to the shower's appearance in 1913. Having eliminated the nights spoiled by moonlight, I recommend the dates mentioned for observations.

TABLE I.

Name	Duration in days	Date of max.	Hourly No. of all meteors on this date	In 1913 observed
Quadrantids	2	Jan. 2	28	
Lyrids	4	Apr. 18	7	Full moon, useless to try.
η Aquarids	8	May 4	7+	May 2 to 8, 3 a. m. to dawn.
δ Aquarids	3	July 28	27	July 27 to 30, midnight to dawn.
Perseids	35	Aug. 11	69	July 28 to Aug. 8, midnight to dawn; Aug. 8-12, 10 p.m. to dawn.
Orionids	14	Oct. 19	21+	Oct. 25 to 28, 11 p.m. to moonrise.
Leonids	3	Nov. 14	21	Nov. 14, after midnight, but moon full.
Andromedes	2	Nov. 24	16	Nov. 23 and 24, 8 p.m. to midnight.
Geminids	14	Dec. 11	23	Dec. 5 to 7, midnight to dawn.

TABLE II. Hourly numbers for whole year.

Hour	6	7	8	9	10	11	12	13	14	15	16
No. of meteors	3.8	4.6	5.6	6.8	8.2	9.8	11.5	13.1	14.4	15.0	14.8

TABLE III. Hourly numbers for each month.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
No. of meteors	8.6	5.6	6.5	6.4	6.0	6.1	11.1	20.6	9.8	14.1	13.3	12.2

Tables II and III will give the observer information as to the number of meteors he can hope to see on a given date and at a given hour. For more detailed information see POPULAR ASTRONOMY, Oct. 1911, pages 524, 525. Observers are strongly urged to attempt observations on as many of the dates mentioned as possible. Since cloudy weather will surely spoil many of them, there will not be a great number left.

CHARLES P. OLIVIER

Agnes Scott College, Decatur, Georgia.

GENERAL NOTES.

The Comstock Prize of the National academy of Sciences has been awarded to Professor R. A. Millikan, of the University of Chicago, for his researches on the charge of the electron, the ratio of electric charge to mass and gaseous ionization. This is the first award of this prize, which is of the value of $1,500.

The Henry Draper Medal of the National Academy of Sciences has been awarded to M. Henri Deslandres, director of the Astrophysical Observatory at Meudon, for his researches in solar and stellar physics.

Professor Willis Luther Moore, who has been chief of the United States Weather Bureau since 1895, will retire from this office on July 31. (*Science* March 28, 1913.)

Astronomical Appropriations.—The annual report of the National Academy of Sciences shows that appropriations were made for astronomical purposes from the Bache fund as follows:

To J. A. Parkhurst, Yerkes Observatory, Williams Bay, Wis., for the determination by photographic methods of the visual and photographic magnitudes and spectral types of faint stars, $500.

To S. C. Chandler, Wellesley Hills, Mass., for the definitive discussion of the latitude variation from 1725 to the present time, $350.

Wireless Time-Signals.—The 1912 report of the Naval Observatory has just come to hand. On page 17 it is stated that noon signals have been sent to ships by radio-telegraphy since 1905. My claim of priority for the Beloit College wireless time service in this country, as stated in the April number of POPULAR ASTRONOMY, is therefore incorrect and I am glad to have this opportunity of correcting my statement.

E. A. FATH.

The Dayton Astronomical Society in the Flood of March 25.—The following letter from Mr. Fosdick adds a personal touch to the interest which was excited by the newspaper accounts of the horrors of the flood which swept over Dayton and other Ohio cities a few weeks ago. The appeal which he makes for books, papers, and slides to help restore the stricken Society is worthy of the most generous response:

No doubt you have seen the accounts in the papers of the great disaster which has befallen our city. It is practically ruined, and will have to be rebuilt, but the citizens are hopeful and have gone to work with a will, and a spirit of good cheer.

The water was fourteen feet deep at Third and Main streets, the center of the city, and was three miles wide. The flood was not caused by the levees breaking. At 8 a.m. Tuesday March 25 the water came in a wave about six feet high over the top of the levees and rolled over the city like a tidal wave, and the water continued rising until it was from ten to eighteen and a half feet deep in the city. From the time the wave came over the levee it was just three hours until it was at its greatest height. Then fires broke out and burned several squares, continuing for several days. It was the most horrible sight one could imagine; no words can describe the awfulness of the suffering and destruction.

Our society has suffered a great loss. All the equipment was ruined, with the exception of the 6″ refractor by Lohman Bros., which was saved. Every book of our library was washed away. My personal library, which was the largest astronomical library in this section, was destroyed and carried out by the flood, as well as about three hundred lantern slides. The damage to my instruments was very heavy. My work-shop was washed away. My wife and self had to run for our lives and we lost everything, with the exception of what we had on our backs. I will furnish you a picture in the near future of the destruction of our instruments.

We shall go to work and try to rebuild and shall make our society stronger and better than before.

If any of the readers of POPULAR ASTRONOMY have any books or slides they would care to donate, that we may be able to re-establish our library and supply of maps, charts and slides, they will be greatly appreciated.

R. E. FOSDICK.

Director of the Dayton Astronomical Society.
Dayton, Ohio. Apr. 12, 1913.

Cosmical Theories: A Criticism.—The following, taken from the *Astronomische Nachrichten* No. 4632, is of interest because it pertains to that part of the sky which on a clear night is so conspicuous and for the explanation of which many theories have been advanced:

"Professor See in *A.N.* 4619 tells us that the distance of the Milky Way is some millions of light years. Let us on this assumption calculate the luminosity of a Milky Way star of the 9th magnitude as compared with the Sun. Assuming the Sun's magnitude to be —26.58, if removed to a distance represented by 2 000 000 light-years, its magnitude would be 29.0 or 20 magnitudes less than a 9th magnitude star. Hence small stars in the Milky Way would have a luminosity 100 000 000 times that of our sun. But this takes no account of the absorption or extinction of light in space. If we adopt the coefficient of absorption (0.999) adopted by Professor See on page 12 of his paper on the Depth of the Milky Way, 1912, the luminosity must be multiplied by a figure greater than 20000, so that on Professor See's assumptions, small stars in the Milky Way have a luminosity

2 000 000 000 000

times that of the sun. I cannot look on Professor See's arguments, which lead up to this, than more than expressions of his opinions on a difficult subject; my own opinion is that the 9th magnitude stars of the Milky Way are strictly comparable in luminosity with the sun.

"There is another point. Could a star exist so large that it is millions of times the mass of the sun? We cannot certainly answer Yes! My own opinion is No! If matter were entirely free from molecular energy, quantities could undoubtedly be added to quantities indefinitely, but matter contains enormous stores of energy and it must at present remain an open question if masses of such matter can be added to indefinitely. A limit may possibly be reached when dissociation on such a violent scale would occur that bodies of the lighter elements would be expelled from the larger mass and double and multiple star systems formed, or the explosion might be of such a uniform type that the resulting effect would be a globular cluster of stars."

R. T. A. INNES.

Johannesburg, 1913 January 20.

The Internal Heat of the Earth as a Source of Energy.—It is a matter of common knowledge that in sinking mining shafts there is a rise in temperature of about one degree Fahrenheit for every 69 feet, down to a certain depth. Active volcanoes afford still more striking evidence of the earth's internal heat.

Have we not here an inexhaustible source of energy? We have, but it is difficult, if not impossible, to utilize it. If the prime requisite in making use of any source of heat is to obtain good conditions of thermal interchange with it, an insuperable obstacle would be found in the poor conducting qualities of rock. Only by fluid convection would it be remotely possible to obtain communication with the earth's stores of heat. In considering these possibilities, the Hon. R. J. Strutt points out that hot springs, while they have been utilized from time immemorial, are too diminutive. The perpetual streams of molten lava that flow into the sea in certain localities, as at Stromboli, might perhaps be utilized, he ventures, "but the opportunities for applying the method would scarcely be extensive enough to encourage inventors."

Why not pump water down to the heated interior and return it to the surface at a high temperature? Here again Strutt sees no possibilities. The pipes would have to be kept immersed in molten lava; no sufficiently rapid transference of heat to them from from solid rock would be possible. For the same reason, he states, the pipes must not be cooled down by the water flowing through them sufficiently to cause the surrounding lava to congeal. Can the pipes endure the prolonged action of molten basalt? Wrought iron might in Strutt's opinion. "On the other hand, the margin of difference between the melting point of basalt and of iron is not very great, and lack of stiffness in iron pipes at such temperatures would undoubtedly introduce the most serious difficulties." Even if the attempt be made by directly attacking a volcanic crater the engineering difficulties would be enormous.

Similar conclusions were reached by Sir Charles A. Parsons in a presidential address to the engineering section of the British Association for the Advancement of Science. He discussed the feasibility of constructing a bore hole twelve miles deep. While the feat could be accomplished, and while the temperature of the rock at that depth is probably 272 deg. Fahrenheit, the undertaking would involve an expenditure of millions. (Waldemar Kaempffert in *Scientific American.* April 5, 1913.)

The Energy of the Rotating Earth.—In an introductory lecture to the engineering classes at University college, London, Professor J. A. Fleming, in considering the sources of energy available to mankind, pointed out that the earth is a great flywheel. It whirls along in its orbit with a velocity of about twenty miles a second or 1,200 times that of an express train. Its rotational energy is a hundred thousand million billion horse-power hours; but the total orbital energy or energy of motion in its orbit is ten thousand times greater. "Suppose" said Professor Fleming, "we could in some way or other slow down its rotation so as to make the day just five minutes longer.....This would decrease the earth's angular velocity by about one third of one per cent and decrease the angular energy by about two thirds of one per cent, or say by 1/150 part. If then we could capture and store up the difference in the rotational energy in the two cases, it would give us about six million billion horse-power hours, or a billion horse-power for seventy thousand years. The energy we can obtain by the combustion of all the one thousand million tons of coal, at present raised per year, sinks into insignificance compared with the enormous energy which would be set free by an almost imperceptible lengthening of the earth's diurnal rotation."

Professor Fleming was not rash enough to indicate in what manner this unthinkable amount of energy could be utilized. Those who will attempt that will find themselves engaged in the mad task of designing perpetual motion machines. (Waldemar Kaempffert in *Scientific American*, April 5, 1913.)

Astrographic Chart and Catalogue.—In the *Monthly Notices* of the Royal Astronomical Society for February 1913 we find the following information concerning the progress which has been made in publishing the Astrographic chart and catalogue:

Observatory and Zone.		No. of Plates in Zone.	No. of Plates Printed.	Details of catalogue.		
	° °					
Greenwich	90 to 65 N	1149	1149	Rect. Co-ords.,	Diams.,	Plate constants.
Rome	64 to 55 N	1140	54	"	Photo. Mags.	
Catania	54 to 47 N	1008	60	"	Photo. Mags.,	R.A. and Dec.
Helsingfors	46 to 40 N	1008	252	"	"	"
Potsdam	39 to 32 N	1232	309	"	"	Constants.
Oxford	31 to 25 N	1180	1180	"	Diameters	"
Paris	24 to 18 N	1260	540	"	Photo Mags.	"
Bordeaux	17 to 11 N	1260	540	"	"	"
Toulouse	10 to 5 N	1080	320	"	"	"
Algiers	4 N to 2 S	1260	280	"	"	"
Perth	32 S to 40 S	1376	80	"	"	"

The printing of the catalogue for Zone 41° to 51°S has begun at the Cape of Good Hope. The progress of the zone taken at the Perth Observatory will perhaps be hindered by the transference of Mr. Cooke to the Directorship of the Sydney Observatory, and for the same reason the work at Sydney may be reorganized. Hitherto the plates taken at Sydney (Zone 52° to 64° S) have been measured and reduced at Melbourne, together with the plates (Zone 65° to 90° S) allotted to the last named observatory.

At San Fernando (3° to 9° S) and at Tacubaya (10° to 16° S) the reduction is proceeding, but as yet no section of the catalogue has been published.

A Tidal Power Plant.—It has long been the dream of engineers to utilize the ebb and flow of the tides for the generation of power on a large scale, but no practical scheme for making the dream a reality has yet been realized. An enormous amount of energy is expended twice each day in lifting the water up the shores of all the continents, and in the recession of the water as the tide ebbs. If all this energy or a considerable portion of it could it be caught and transformed into practical forms of power for operating machinery it would be of tremendous value to the business of the world. The latest plan for utilizing the energy of the tides is given in *The Electrical Review* (London, February 21) in the description of a proposed tidal power-plant at Husum, on the Schleswig-Holstein coast of the North Sea. A reservoir of 4000 acres is to be created by means of embankments between the Isle of Nordstrand and the mainland. The reservoir will be divided into an upper and a lower tank, communicating by sluices with the shallow inland sea on the one hand and with the turbine-plant on the other.

The Literary Digest, April 5, 1913, gives the following quotations from the original article in *The Review*, showing how the German engineers are planning to accomplish the transformation of energy:

"The scheme is based on the assumption of a uniform tidal amplitude of ten feet, the lowest ebb and highest flood each time reaching the same level, and their difference of level always being ten feet. Under this assumption the working of the plant will be as follows: When the water in the sea is higher than the upper reservoir, this will be filled through the sluices; if, on the other hand, the water in the upper reservoir be at a higher level, this will flow off through the turbines, thus actuating the latter. This would commence some time after the beginning of low

tide and cease shortly after the beginning of high tide. An opposite process is to take place in the lower tank; when the water in the sea is higher than in the tank it will flow in through the turbines, thus starting these some time after the beginning of high tide, and stopping them some time after the beginning of low tide. If the water in the sea be lower than in the tank, water will flow from the latter through sluices into the sea.

"The promoters of this scheme, on the hypothesis of a regular return of tidal amplitudes, presume that the operation of the turbines from one of the tanks may begin at the very moment the operation from the other tank ceases, thus ensuring a continuous service; they are reckoning on a level difference of five or six feet between the sea and the tank actually in operation, the water in both tanks rising and falling about three feet during each tide.

"The turbines are to yield 5000 horsepower, driving dynamos which will work without any accumulators, thus communicating their output directly to the supply system. The cost of construction is estimated at $1,250,000 of which about $875,000 is allowed for the embankments and about $125,000 each for the turbines and sluices, the buildings and electrical part of the plant. The cost of the kilowatt hour, as produced in the tidal electricity works, has been calculated in the first instance at 2½ cents, but in the event of a large consumption it will be reduced considerably (down to half a cent or less). Even should the electrical enterprise fail, the promoters would in any case recover the value of the land reclaimed from the sea."

Criticism of this plan is not lacking. It is asserted that the fluctuations of the tidal level are often unexpected and abrupt; that the dynamos would not work continuously, but there would be at least two hours of rest between periods of operation; the transmission lines required to take the power to where it may be used will be enormously long; the machinery has not been well planned, the foundations are in mud and the figures for the cost are extremely doubtful.

Whether the promoters or the critics are right remains to be seen, but it will be interesting to astronomers as well as engineers to see the attempt thus made to utilize the energy which comes more directly from the gravitation of the moon and sun than do those forms of energy which have been utilized hitherto.

Reducing Negatives.—The reduction of a negative may become necessary for any one of several reasons. It may be over-developed and require proportional reduction all over; or it may be too flat and require reduction in the shadows so that they may print darker; or it may be too steep in contrast and require reduction in the high-lights; or, finally, it may simply be veiled or fogged and require clearing.

SUIT THE REDUCER TO THE NEGATIVE.

Each of these purposes requires a little different treatment, hence there are several methods of reduction in common use. Many are, however, afraid to attempt such work for fear of failure, the commonest form of which is perhaps uneven action; but there is no real need to fear any such effect if one general precaution is taken. The negative must be thoroughly well saturated with water before any attempt is made to reduce it with the aid of any solvent solution, and if a complete soaking is given there is no reason for anticipating failure at all, provided, of course, that the process of reduction is not carried too far.

Clean and then Soak the Negative.

The first operation is, therefore, soaking the negative, and if there is any suspicion of grease on the film, this grease should be cleaned off with a little ether or alcohol before the soaking begins. It is a good plan always to soak for half an hour, for though a less time may be sufficient with some negatives, it will not be so with all, and it is essential to be on the safe side.

Farmer's Reducer for Flat and "Line" Negatives.

The most generally useful of all reducers is Farmer's, which, as every photographer knows, consists of a hypo solution to which a little potassium ferricyanide has been added. The hypo solution must be fresh; that is to say, we must not take a portion of a fixing bath that has been used for fixing, unless we want to risk stains; but we may quite well keep the hypo in a stock bottle. About ten per cent strength (2 ozs. per pint) is most useful for reduction, a stronger solution being inadvisable. Further, the solution must be one of plain hypo, and not a stock acid fixing bath. Acids should he kept out of the reducer because they decompose the ferricyanide, but a little alkali will do no harm, and the addition of a few drops of ammonia is sometimes recommended, though the effect in my experience is not at all appreciable. The ferricyanide is best kept in a stock solution, and if this solution is of 20 per cent, strength (4 ozs. to the pint) and made with distilled water it will keep indefinitely, and always be ready for use. Weaker solutions will not keep, and it is useless to make them up.

How to Prepare Farmer's Reducer.

A great deal has been written upon the right proportions of hypo and ferricyanide, but in practice it is unnecessary to worry about them. It is quite sufficient to judge the solution by its colour. Adding drops of the ferricyanide to the hypo until a faint straw colour is reached gives what we may call a weak reducer. One or two drops to the ounce will be enough for this, and double the quantity will give a strong reducer of a bright yellow colour. If too much is added we can dilute with water.

The peculiarity of Farmer's reducer is that it reduces the shadows to a greater relative extent than the high-lights, and is therefore eminently well suited to over-exposed negatives, or to clearing away fog on a line negative where we want clear glass to show. With ordinary negatives for general reduction purposes it is always best to use a weak solution that acts slowly, this being applied in a dish; but when clearing off fog or "cutting" the lines on a process negative we want a strong solution that acts quickly, the process being best carried out by applying the reducer to the lines with a pad of cotton wool, then immediately plunging the negative into a stream of water from a tap. This process is repeated until the lines are clear glass; but while it is a fairly safe and easy process with a line negative it is somewhat risky with an ordinary negative. When the shadows require extra reduction, or when there is overmuch fog to contend with, it is a useful method to employ, but great care is wanted. On the other hand, the slow method with a weak solution in a dish is quite safe, and only requires watching so that the process may be stopped when it has gone far enough. The dish should be kept rocking all the time, and the best stop that can be used is plain water and plenty of it.

The high-lights are, of course, reduced at the same time as the shadows, though not at the same rate, hence if much action is required in the shadows the high-lights may eventually be too weak. In this case intensification must be the next process, but this is not likely to be wanted unless the negative was a very flat one in the first instance. If the trouble is mainly fog, this will quickly be removed if it is due to undue exposure to the "safe light" or if due to slight over-exposure. If, however,

its cause is excessive over-exposure, or if it is bad chemical fog formed by a wrongly composed developer or a "fogged" emulsion, the remedy will fail, for such fog is too deep-seated in the film to be dissolved out except at the expense of the details. Moderate over-exposure, or over-development, or slight light-fog will, however, very quickly be remedied by the use of a weak Farmer's solution.

REDUCE WITH ALL OR NO FIXER IN THE FILM.

A warning is necessary with regard to freshly fixed negatives. These should either be put straight into the reducer from the fixing bath, or else very thoroughly washed before reduction. Any intermediate course is fatal, for if the hypo is imperfectly washed out uneven action will result. The first method is often convenient, but if the fixer is not quite fresh and clean stains may result. It is safest to put the negative through a quite fresh, plain fixing bath before applying the reducer.

(*British Journal of Photography,*) Feb. 14, 1913.

Proposition for an Organization for Systematic Observation of the Minor Planets. (*Translated from the German by Professor A. E. Vestling, Carleton College.*)—Observations of the smaller planets are at present made quite without any definite method as is shown by the literature on the subject; at each opposition observation upon observation is made upon one object while some other remains unobserved for years. Whatever ones opinion may be as to the question whether regular series of observations are required for all the minor planets and how extensive these observations should be, yet it will be generally conceded that if it is possible by some mutual agreement to secure a more equal distribution of observations without an increase in the amount of work (of course special attention may at the same time be given interesting objects), that plan would be preferable to the present status. Since the desire to make planetary observations is very widespread, as is shown by the published series of observations and by numerous communications received by the undersigned, and since there are numerous instruments and observers available for this purpose, there is need only of a systematic organization, to make efficient use of these agencies. With some such idea as this in mind the conference which met last year at Paris declared in favor of a unification and simplification in the construction of the Astronomical Year Books. (General Resolution VII. The conference expresses the wish, that the observers should adopt some uniform plan for making systematic observations of all asteroids.) The undersigned is obeying repeated requests from various sources in suggesting such an organization by this circular letter. Since the *Astronomisches Rechen-Institut* (Berlin) at present makes the computations necessary for the further investigation of the small planets and especially for the verification of new discoveries, it would quite naturally be the most suitable central station for the systematic organization of the observations and it is very willing to assume the work which this would entail. The undersigned hereby requests the observers to let him know their opinion in regard to such an agreement; he himself makes the following proposition without in any way wishing to exclude more efficient plans.

I. THE OLDER PLANETS.

Observations are at the present time of two kinds, photographic which are usually only roughly estimated, and visual exact observations. The first as a rule form the basis for the latter, since the preliminary computation of the location can not at present be made with sufficient exactness for visual discovery without altogether

too much work. On the other hand the approximate ephemerides * near the time of opposition which the *Berliner Jahrbuch* provides for all the planets serves as an aid for the photographic observations. If by means of photographic plates the corrections to these ephemerides are determined and made known as soon as possible, the object can be found visually at the same opposition and observed accurately. The undersigned takes for granted that this method of observation will be retained for the present.†

An organization of photographic observers (*Beljawski*-Simeis, *Gonnessiat*-Algiers, *Innes and Wood*-Johannesburg, *Metcalf*-Winchester, *and Wolf*-Heidelberg) worked successfully last year. Its purpose is to study as regularly as possible all asteroids so that from one to two photographic plates may be obtained at each opposition (with the exception of those which are too faint). By this means it will also be possible to improve the ephemerides of the *Berliner Jahrbuch* continually. Those sharing in the work will give their especial attention to certain zones, without in any way being limited in their other observations. It is expected that the number of participants will soon increase.

It is then very desirable that there should be an organization of the visual observers also. Here too repeated observations—two to three would be fully sufficient—could be made at every second or third opposition. The distribution of the various planets among the observers who wish to participate in such a plan might be based upon the following considerations:

1.) Declination of the object.
2.) Brightness of the object.
3.) The need of observations.

The choice between the first two would be made by the participants; it would depend upon the location of the observatory and the available instruments. Point 3, the need of observations, can probably be best determined at the central station. This station can most easily call attention to the planets which have not been observed visually for a long time and which therefore are in need of observation. For example the request may also be made to give a longer series of observations to a planet, whose first orbit is not satisfactorily established, in order to bring about a new and more accurate determination of its orbit.

The prompt transmission of the corrections to the ephemerides of the *Berliner Jahrbuch* to those who wish to participate in this organization, could best be done by the *Rechen-Institut*, because the results obtained by the photographic observers will be reported to this institute, and especially because the at times very doubtful identifications will be tested and the new discoveries announced as such. But since this, at least for the present, can be done only by correspondence, a prompt notification is possible only for the European observatories (including Algiers). The observatories outside of Europe, whose participation is very desirable, in fact urgently necessary, are therefore for the present dependent upon the nearest place of photographic observation (Winchester for the U. S. A. and Johannesburg for South Africa) for direct information. For the European observatories too, much time can be saved by direct communication between the visual and photographic observers. This direct connection exists between the following observers: *Wolf*-Heidelberg, *Palisa*-Vienna, and *Javelle*-Nice.

* These ephemerides from 1914 on (*B. J.* for 1916) will give five positions at eight day intervals, together with, when possible, the change $\Delta\delta$ for $\Delta\alpha = 1^m$.

† If in the future the number of photographic observers should be greatly increased, it is probable that they alone would furnish all the necessary material for the complete identification of the minor planets, especially those newly discovered.

The attempt should now be made to distribute the total number of the minor planets among the participants in such a way that there would be no useless accumulation of observations. The organization is intended to be as simple and unrestricted as possible and only to pledge each participant to give his *particular* attention to a definite group of minor planets. Since any strict division of the planets will probably not be possible, but rather a number of observers will choose their objects from the same larger group, the *Astronomische Rechen-Institut* should be informed immediately (date and approximate position would suffice) of every successful observation (possibly also of every unsuccessful search), so that other observers might be notified promptly and useless observations avoided. Certain observatories (for example those of one country) might combine for the observation of such a group and have a mutual understanding in regard to details, so that only the central station of the country concerned would need to be notified by us.

II. The Newly Discovered Planets.

Visual study of the newly discovered planets, which for the most part are very faint, is especially difficult. Besides Mr. Palisa, who for some years has tried to follow the photographic discoveries made by Mr. Wolf in Heidelberg, until their orbits are positively determined, Mr. Javelle(Nice) has recently begun to take a regular share in this task. Yet a considerable number of the new discoveries are still lost track of; in view of the present systematic organization of photographic observers more numerous new discoveries may be expected. The first thing after the photographic discovery is the visual location of the object, which often causes great difficulty in view of the loss of time caused by the lack of telegraphic communication. The establishment of direct telegraphic communication between the photographic discoverers, the *Astronomische Rechen-Institut* and the observers who wish to participate in the visual work upon the new discoveries would therefore be very desirable. In every case the observer should immediately inform the discoverer (or the *Rechen-Institut*) if unsuccessful, so that the discoverer might verify the object by a second photograph. Such a prompt second photograph would always obviate useless loss of time in the visual search and in this way considerably facilitate the work of the visual observer, especially in the case of very faint objects, the finding of which, according to the experience of Mr. Palisa, is especially difficult because of the only approximate indication of their daily movement, and which often can not be found at all without a second photograph. The *Rechen-Institut* is very willing to act as central station, to send information of this nature by telegraph when necessary, to compute a provisional orbit when this is desired, after receiving the necessary observations and to compute an ephemeris for further work. In each case every successful observation should immediately be forwarded to the institute.

For the new discoveries in Johannesburg and Winchester, news of which reach Europe too late or which lie too far south, nearer participants with efficient instruments are very much desired, who must then be immediately informed concerning each new discovery.

A planet may be considered as established only when careful visual observations exist of such number and extent, that an elliptical orbit can be computed with some degree of certainty. For this there is required a series of observations extending over a period of from six to eight weeks and including about five or six exact observations. For upon this depends to a very large extent the possibility of finding these planets again, since as a rule the planets are discovered in comparatively favorable oppo-

sitions and in the succeeding ones are considerably fainter and thus can be discovered again only after a number of years. Otherwise they are lost for a long time and are discovered again only by chance.

The notification of the first successful observation should therefore also state whether the observer intends and has the equipment necessary to continue the observations until the orbit is positively determined, so that other observers may turn their attention to other objects, or, in order that if there are difficulties in the way, further assistance may be given, in case of necessity, by new photographs before too late. There should also be a statement as to whether an ephemeris for the further study of the planet is wanted, also that the necessary measurements for the determination of an orbit have not been secured (in such cases as this should occur), in order that the lacking observation may be provided by the photographic observer.

It is very desirable that a number of observers (photographic and visual) as soon as possible declare their willingness to coöperate, express their opinion in regard to the questions outlined, or make more practical propositions, and indicate in what way they would care to participate, and what objects they would prefer to devote their attention to, in order that a complete understanding might be arrived at by all those participating in such an organization.

FRITZ COHN.

Kgl. Astronomisches Rechen-Institut.
Berlin-Dahlem, January 1913.

The Rapid Drying of Plates.—When dry-plates are used, the time consumed when they are allowed to dry spontaneously can frequently ill be spared. Resort is then generally had to soaking in spirit, but the more hurried the operation the less satisfactory is this method. For if a plate has not been thoroughly washed or thoroughly fixed and the spirit be not over strong, the negatives will show opalescent markings which are yellow to transmitted light. Such a negative is useless for printing. Another disadvantage of the spirlt method is that it is expensive, as the spirit needs constant renewal, owing to its rapid weakening by the addition of water from the negative, and loss by evaporation. A much better method is to soak the negative for a few minutes in a ten per cent solution for formaline. Two minutes is quite sufficient with some makes of plates. After this soaking the negative is rinsed, the superfluous moisture is swabbed off, and the plate may be dried by heat, over a flame if necessary. (*The British Journal of Photography* March 14, 1913.)

Handbook of Nature Study, for Teachers and Parents.—Anna Botsford Comstock, B. S., Lecturer on Nature Study, Cornell University, etc., 938 pages. In one volume $3.25, postpaid $3.65; in two volumes $4.00, postpaid $4.50. Comstock Publishing Co., Ithaca, N. Y.

This is one of the few Nature Study books which gives a number of lessons on the study of the sky, and that is the excuse for mentioning it in an astronomical magazine. The whole book is well written, profusely illustrated and splendidly printed on fine plate paper. With this in hand the teacher of nature study in the grades should not be at a loss how to present the subjects in an interesting manner to her pupils. Pages 887 to 923 are devoted to Sky Study, and present in a very simple and interesting way the study of the constellations, their nightly movements, the winter stars, the summer stars, the sun and its family, comets, shooting stars, the zodiac and its signs, the relation of the sun to the earth, the moon and its phases. Each lesson is followed by numerous questions, the solution of which will require the pupil to observe the objects in question for himself.